REPORT ON PUERTO RICO TSUNAMI FLOOD MAPS FOR LOCAL EVENTS

submitted to the

Puerto Rico Component of the

United States

National Tsunami Hazard Mitigation Program

and the

Puerto Rico Seismic Network

Geology Department

University of Puerto Rico

Mayaguez, P.R.

February 2014

by

Aurelio Mercado

Department of Marine Sciences

University of Puerto Rico/Mayaguez, P.R.

TABLE OF CONTENTS

TABLE OF FIGURES

INTRODUCTION

This report concerns the tsunami inundation modeling carried out for local tsunamis carried out under the mandate of the USA National Tsunami Hazard Mitigation Program.

MODEL USED

MOST, version most3_facts_nc.f. A constant Manning coefficient of 0.03 was used, a value suggested by Dr. Diego Arcas (PMEL) when A. Mercado was doing SIFT maps under direct contract by the National Center for Tsunami Research. There is a generation/propagation version, and an inundation version. Both were used in the modeling effort.

BATHYMETRY/TOPOGRAPHY USED AND COMPUTATIONAL GRIDS

The version of MOST used comes in two versions. The first version has to do with generation and propagation of the tsunami. Figure 1 show the propagation grid used for both regional and local tsunamis, which has a resolution of 60 arc seconds (approximately 1800 m). This grid was prepared from data supplied by Dr. Diego Arcas.

For the inundation grids, the data was obtained from the National Geophysical Data Center Digital Elevation Model for Puerto Rico, with 1 arc seconds resolution (approximately 30 m). This included nearshore bathymetry. The deep water bathymetry used was the same as supplied by PMEL/NOAA when doing SIFT modeling for NOAA.

The second version takes care of the inundation phase. Due to software limitations, and to the desire to do high-resolution inundation modeling (30 m resolution), Puerto Rico (including its two island municipalities to the east: Vieques and Culebra) was broken down into three parts: East, Central, and West. This is shown in Figure 2, which shows the geographical coverage of the three inundation grids. Grid A is the larger, lower resolution, 60 arc-seconds grid. Grid B is the intermediate resolution grid (9 arc seconds; approximately 270 m resolution). There are three inner grids (Grids C: East, Central, West), each with a resolution of 1 arc second (approximately 30 m).

Figures 3 to 5 show each individual inundation grid. They also show the location of tsunami-ready tide gauges (white crosses) and a few additional virtual ones placed for coverage purposes. Below each figure the parameters describing each grid are given. Tables 1 to 3 show basic statistics for the three inundation grids.

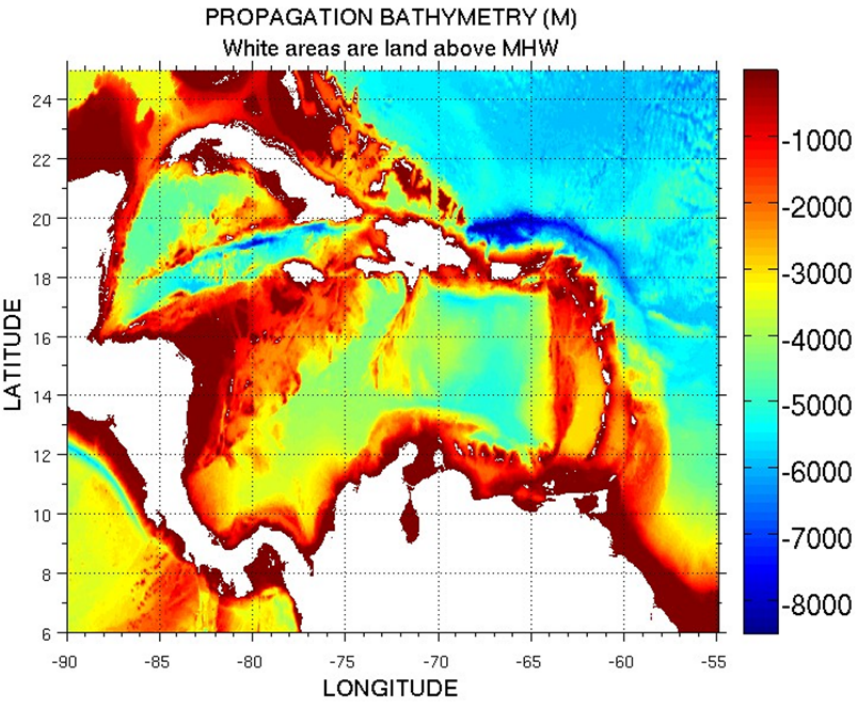

Figure 1 – Propagation grid. Computational cell resolution: 60 arc seconds.

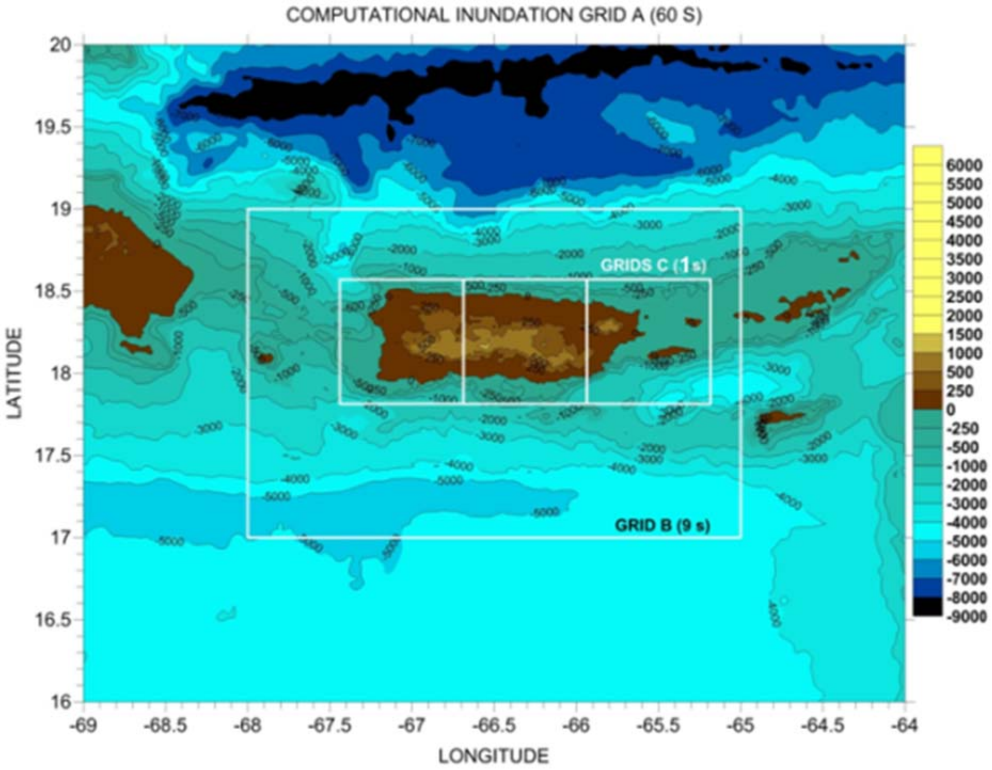

Figure 2 - Computational inundation Grid A. The outlines of the in8undation Grids B and C are also shown.

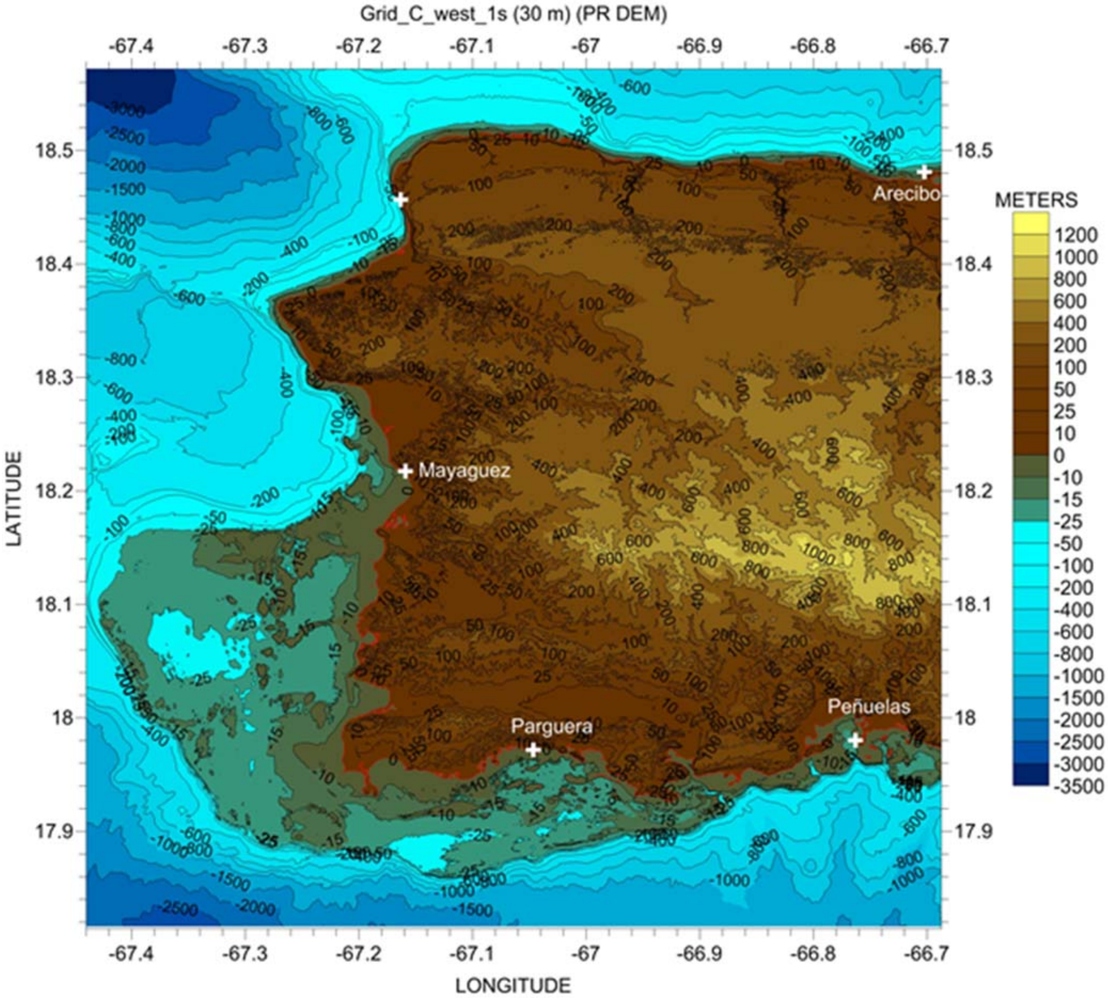

Figure 3 – High-resolution Grid C west used for inundation modeling. White crosses indicate location of tsunami-ready tide gauges.

Table 1: Basic statistics for the West inundation grid.

Cwest	
Grid File Name:	west.grd
Grid Size:	2752 rows x 2845 columns
Total Nodes:	7829440
Grid Geometry	
X Minimum:	-67.360972212943
X Maximum:	-66.570972209053
X Spacing:	0.00027777777914557 (30 m)
Y Minimum:	17.81625001
Y Maximum:	18.58041668
Y Spacing:	0.00027777777898946 (30 m)
Zmin (m):	-2999.49993302
Zmax (m):	1330.41986484
Δt:	0.17 sec

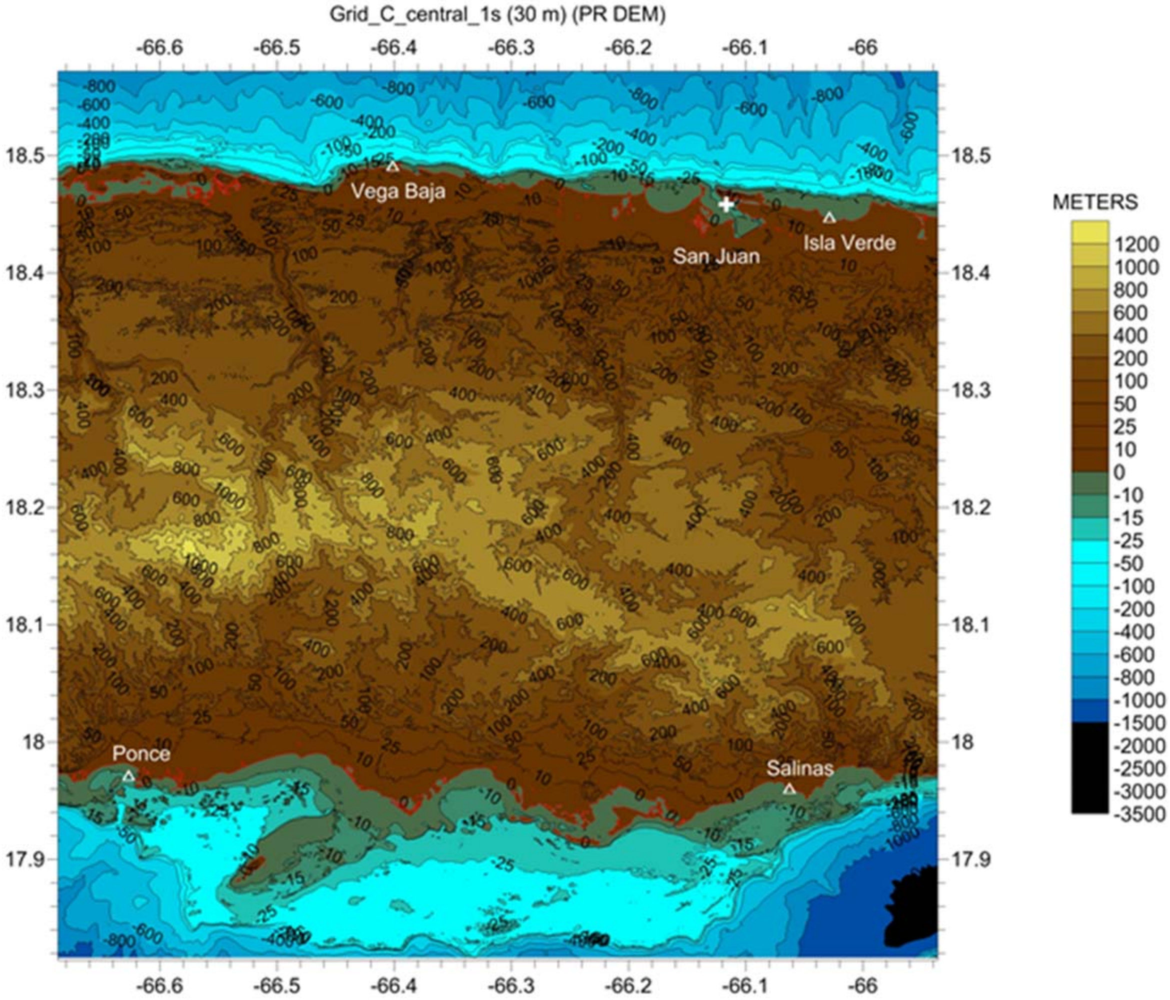

Figure 4 - High-resolution Grid C west used for inundation modeling. White crosses indicate location of tsunami-ready tide gauges. White triangles are supplementary virtual tide stations.

Table 2: Basic statistics for the Central inundation grid.

Ccentral	
Grid File Name:	central.grd
Grid Size:	2752 rows x 2843 columns
Total Nodes:	7823936
Grid Geometry	
X Minimum:	-66.57208332017
X Maximum:	-65.782638871838
X Spacing:	0.00027777777914567 (30 m)
Y Minimum:	17.81625001
Y Maximum:	18.58041668
Y Spacing:	0.00027777777898946 (30 m)
Zmin (m):	-1989.91999738
Zmax (m):	1300.88983793
Δt:	0.21 sec

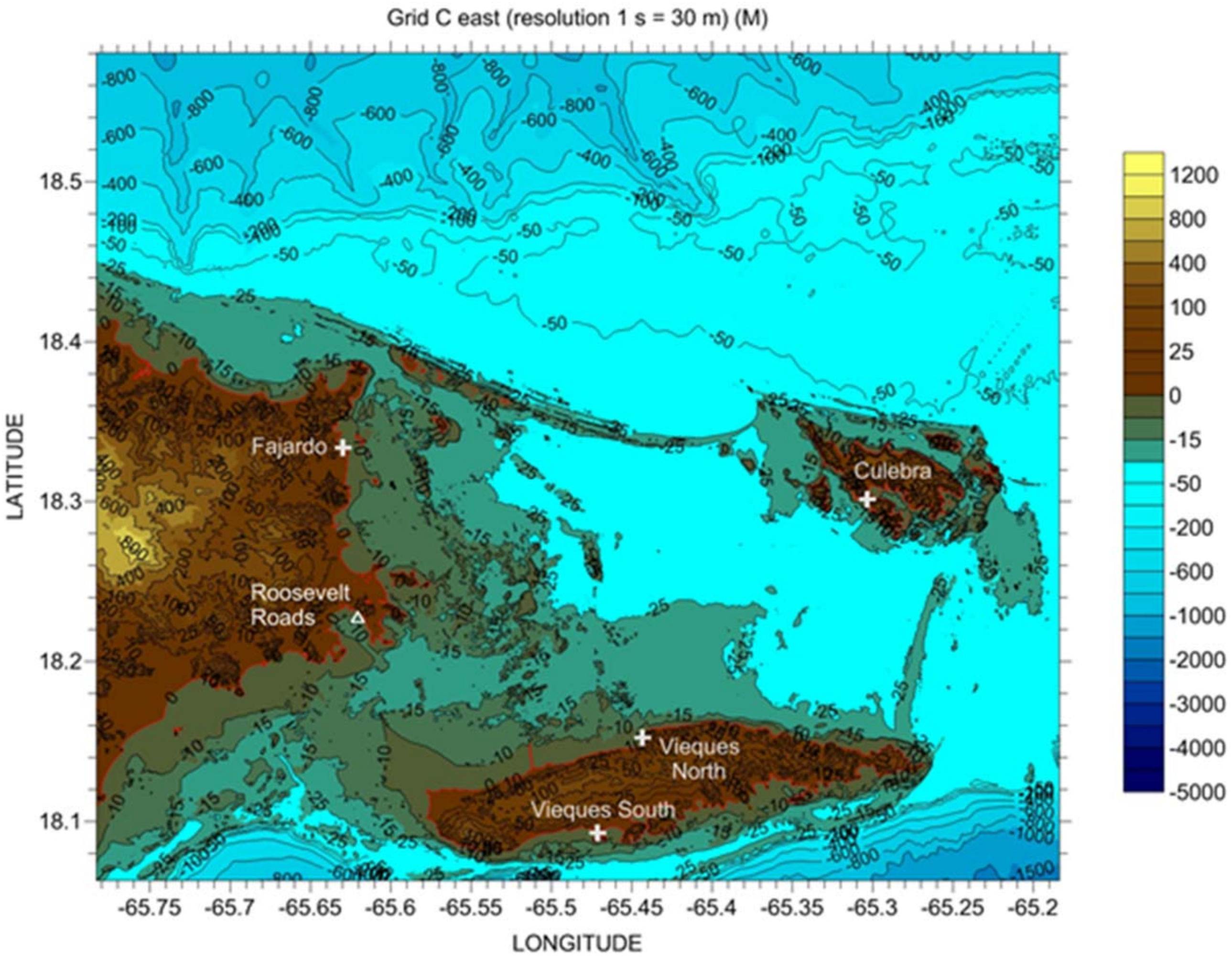

Figure 5 - **High-resolution Grid C west used for inundation modeling. White crosses indicate location of tsunami-ready tide gauges. White triangles are supplementary virtual tide stations.**

Table 3: Basic statistics for the East inundation grid.

Ceast	
Grid File Name:	east.grd
Grid Size:	1863 rows x 2159 columns
Total Nodes:	4022217
Grid Geometry	
X Minimum:	-65.783194427396
X Maximum:	-65.18374998
X Spacing:	0.0002777777791455 (30 m)
Y Minimum:	18.063194455522
Y Maximum:	18.58041668
Y Spacing:	0.00027777777898926 (30 m)
Zmin (m):	-1796.88990318
Zmax (m):	1041.68996102
Δt:	0.22 sec

Finally, Figure 6 shows the mosaic generated by joining the three grids. Model results will be shown for each individual grid, and for the mosaic. Movies can only be shown for the propagation and each of the individual inundation grids.

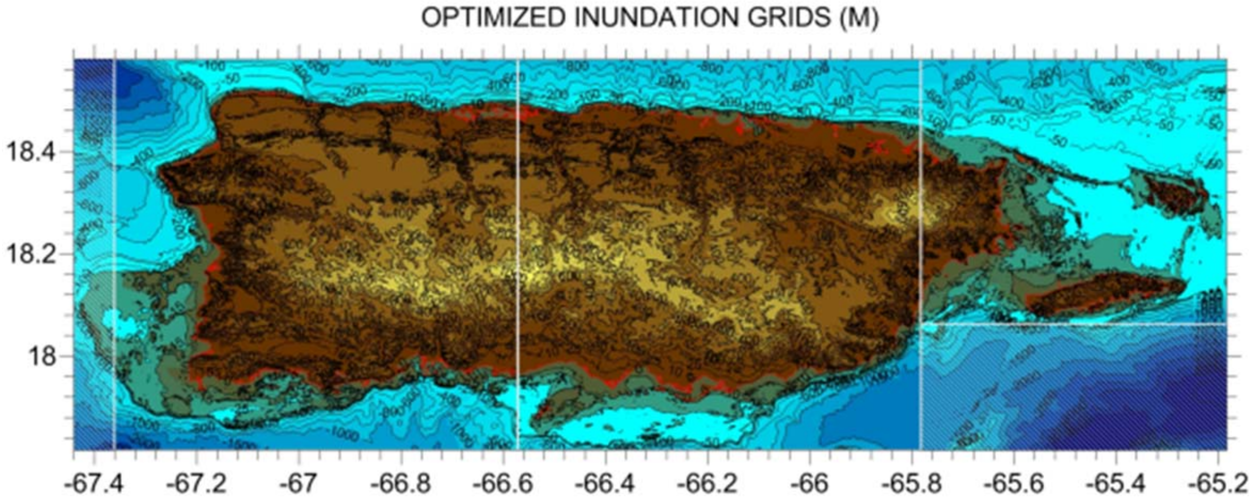

Figure 6 – Mosaic of the three inundation grids. In the final version of the east grid the southern part was cutoff in order to speed up the computations. The section that was cutoff corresponds to the rectangle at the southeast corner of the mosaic.

In order to have an idea of the strength of the tsunami signal reaching the island, and its duration, virtual gauges were placed offshore of each one of the four coasts at a sufficient water depth so that nonlinear effects should not be manifested. The location of each gauge is shown in Table 4 and shown in Figure 7.

Table 4: Location of offshore virtual tide gauges for propagation purposes

Gauge	Longitude (°)	Latitude (°)	Water Depth (m)
North coast	-66.48332863	18.500000263	224
West coast	-67.24999545	18.2000002568421	150
South coast	-66.48332863	17.850002494	50
East coast	-65.44999509	18.300002589474	31

In this report, for each tsunami scenario we will present a table listing the input parameters used to execute the generation/propagation runs, and another table showing the input parameters used to execute the inundation runs. For the propagation results three figures will be shown:

- Figure of the initial bottom deformation. In this figure the lower and upper limits of the color bar is set based on the minimum and maximum of the bottom/sea surface deformation.
- Figure of the maximum water elevation attained in each computational cell, relative to Mean High Water (this is the vertical datum of the NGDC DEM). This is what is called the Maximum Envelope of Waters (**MEOW**), a terminology used in the storm surge community. In this figure the upper limit of the color bar is set based on the maximum sea surface elevation computed anywhere in the computational grid.

- The four offshore time series mentioned above.

Figure 7 – Google Earth view of the location of offshore wave buoys used for observing propagation time series. See Table 4 for coordinates.

For the inundation runs, and for each one of the three inundation grids, the following figures will be shown

- A figure showing the MEOW for that grid (relative to MHW). In these figures the upper limit of the color bar is fixed at a value of 2 m above MHW. But each figure will list the maximum water relative to MHW attained somewhere in the grid, and its location.
- A figure showing the inundation water depth (that is, relative to the local terrain elevation). These are symbolized by the string LWD. The upper limit of the color bar is also set at 2 m.
- A figure showing the time series of water elevation at each of the water gauges for each of the three inundation grids.
- A figure showing a mosaic (that is, all three inundation grids put together) of the MEOW.
- A figure showing a mosaic of the inundation water depth (that is, relative to the local terrain elevation). This is symbolized by the string LWD (Local Water Depth).
- A figure showing a mosaic where areas with sea surface elevations above 1 m are painted red, sea surface elevations between 0.3 and 1 m are painted gold, sea surface elevations above 0 m and 0.29 m are painted blue, and areas not flooded are painted white. These are the breakdown limits used by the tsunami warning centers to describe the tsunami hazard.
- In addition, for each of the three inner grids movies and kmz files are available. A kmz is also available for the mosaics.

ISSUES CONCERNING MOST

1. The combination of very irregular, and steep, bathymetry with a hydrostatic model like MOST forces to do a lot of smoothing of the computational grids. This is of concern since results may differ somewhat from results coming out of non-smoothed grids. There is also concern about dispersion effects when shoaling along a very steep bathymetry like in Puerto Rico. And also about resonance in bays and harbors.
2. One has to be careful in specifying the fault location, or origin. Figure 8 shows the deformation plane. In my experience, I have seen at least four fault locations used: 1) the upper left hand corner, 2) the lower left hand corner, 3) the center of the fault plane, while (4) the red triangle shows the fault location assumed by MOST. Henceforth, when a fault location is given one has to ask which of the three locations is being used, and convert the location to the place where MOST expects it. In the figures below showing the fault traces we are starting the trace at the upper left hand corner of the fault plane. The MOST propagation source code was modified by us so that in the MOST input parameters file the first line informs whether the given fault location lies in the upper left hand corner, in which case a subroutine was added that changes the location to the middle of the lower border of the fault plane, as expected by MOST. If the given fault location follows the MOST convention, then no changes are made.

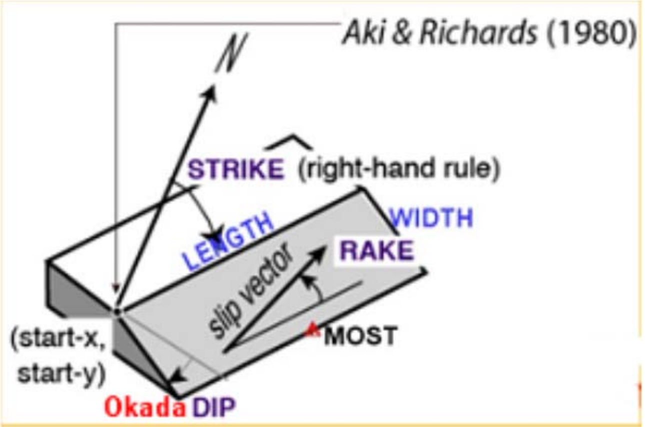

Figure 8 – Fault plane showing locations used to locate it. The red triangle at the middle of the bottom edge is the location expected by MOST.

3. Although MOST runs in serial mode, the fact that the island was divided into three sections (East, Center, West), and all three were run at the same time, is like running the model in parallel mode (Domain Decomposition). But even then, the wall-clock time for the West section was typically on the order of 12 days for two hours of simulation. The Center section wall-clock time was on the order of 9-10 days, and the East section about a week. The workstation used had 48 64-bits cores, AMD Opteron, with 98 GB of RAM. This created problems when the electricity went out for long times, and the execution was stopped, and we had to start all over again. Or when the model crashed, and we had to either do further smoothing, and start again. The combination of small computational grid size (order of 30 m), with very deep bathymetry

very close to the shore, forced a small computational time step. The bottom line is the need for parallel programs.

4. The following issue concerns high-resolution modeling, and it is where does one throw the line in deciding whether a large runup is acceptable, or it is completely unreasonable. For example, should we consider a 25 m high runup as possible, or blame it on a numerical instability? It is my feeling that the higher the resolution, the more frequent we will come across large runups.
5. The following comments concerns rivers. It is well known that rivers serve as conduits for inland flooding, sometimes miles inland. The 30 meters resolution of the computational grids allows for the model to “see” the main rivers in the island. But the concern is with the river depths. It is not clear whether the Lidar penetrates the typically turbid waters of the rivers. So it is highly possible that the what the model is seeing when the tsunami is penetrating a river is a very shallow river and it is not clear whether this would under predict, or over predict, the inland flooding.
6. Finally, a very important issue is the fact that MOST requires a single value of the Manning friction factor. A value of 0.03 was used, a value that can signify flow over different types of terrains (see Appendix 1), but certainly not flow over dense, tropical, vegetation, nor highly packed reinforced concrete infrastructure as is typical in coastal areas of Puerto Rico. Nor will it represent flow over offshore reefs, fringing reefs, or mangroves, as found in Puerto Rico. This will tend to produce larger flooding areas than with more realistic bottom friction factors. Caveat emptor.

METHODOLOGY

In this report for local scenarios we have used the same scenarios in twelve regions as done in the previous tsunami flood mapping for Puerto Rico, sponsored by FEMA, and finished in 2003. A report on how the scenarios were determined is found in http://poseidon.uprm.edu/, Project Reports, “Mode of Faulting in the Local Zone of Puerto Rico (LZPR)”, by Dr. Victor Huerfano. As described below, eight additional local historical earthquakes were also included. Finally, a so-called FEMA Catastrophic Scenario was also added. This scenario was proposed, and discussed, by local experts, including scientists from the USGS, Homeland Security/FEMA, NOAA, Argonne National laboratory, and Los Alamos National Laboratory. Figure 9 shows the fault traces for all local events. We will show next the input parameters used for the three inner, high-resolution, grids C (East, Center, West), in this case for fault f01 of Muertos Trough.

East Grid:

0.0050	Minimum amp. of input offshore wave (m)
5.0	Minimum depth of offshore (m)
0.1	Dry land depth of inundation (m)
0.0009	Friction coefficient (n**2)
1	Let A-Grid and B-Grid run up
200.0	Max eta before blow-up (m)
0.21	Time step (sec)
34286	Total number of time steps in run (2 hrs)

```
28        Time steps between A-Grid computations
4         Time steps between B-Grid computations
112       Time steps between output steps (23.5 s)
1         Time steps before saving first output step
1         Save output every n-th grid point
'/home4/amercado/NTHMP_PR/inundation/grids/grid_A_60s_inun_v2.dat'
'/home4/amercado/NTHMP_PR/inundation/grids/grid_B_9s_inun_v2.dat'
'/home4/amercado/NTHMP_PR/inundation/grids/east.dat'
'/yeyi01/amercado/NTHMP_PR/results/propagation/local/Victor/Muertos_Trough/f01/'
'./'
0 0 1 1 Produce/Suppress netCDF output for grids (default: 1 1 1 0)
0     Number of timeseries locations
3 1008 1430 timeseries index (grid number, i, j)
```

Center Grid:

```
0.0050  Minimum amp. of input offshore wave (m)
5.0     Minimum depth of offshore (m)
0.1     Dry land depth of inundation (m)
0.0009  Friction coefficient (n**2)
1       Let A-Grid and B-Grid run up
200.0   Max eta before blow-up (m)
0.20    Time step (sec)
36000   Total number of time steps in run (2 hrs)
30      Time steps between A-Grid computations
5       Time steps between B-Grid computations
90      Time steps between output steps (18 s)
1       Time steps before saving first output step
1       Save output every n-th grid point
'/home4/amercado/NTHMP_PR/inundation/grids/grid_A_60s_inun_v2.dat'
'/home4/amercado/NTHMP_PR/inundation/grids/grid_B_9s_inun_v2.dat'
'/home4/amercado/NTHMP_PR/inundation/grids/central.dat'
'/yeyi01/amercado/NTHMP_PR/results/propagation/local/Victor/Muertos_Trough/f01/'
'./'
0 0 1 1 Produce/Suppress netCDF output for grids (default: 1 1 1 0)
0     Number of timeseries locations
3 1008 1430 timeseries index (grid number, i, j)
```

West Grid:

```
0.0050  Minimum amp. of input offshore wave (m)
5.0     Minimum depth of offshore (m)
0.1     Dry land depth of inundation (m)
0.0009  Friction coefficient (n**2)
1       Let A-Grid and B-Grid run up
200.0   Max eta before blow-up (m)
0.16    Time step (sec)
45000   Total number of time steps in run (2 hrs)
36      Time steps between A-Grid computations
6       Time steps between B-Grid computations
```

```
180      Time steps between output steps (28.8 s)
1        Time steps before saving first output step
1        Save output every n-th grid point
'/home4/amercado/NTHMP_PR/inundation/grids/grid_A_60s_inun_v2.dat'
'/home4/amercado/NTHMP_PR/inundation/grids/grid_B_9s_inun_v2.dat'
'/home4/amercado/NTHMP_PR/inundation/grids/west.dat'
'/yeyi01/amercado/NTHMP_PR/results/propagation/local/Victor/Muertos_Trough/f01/'
'./'
0 0 1 1 Produce/Suppress netCDF output for grids (default: 1 1 1 0)
0     Number of timeseries locations
3 1008 1430 timeseries index (grid number, i, j)
```

As in the previous 2000-2003 FEMA study, the tsunami scenarios have been broken into 12 regions, called 19° N, Anegada, Eastern Dominican Republic, Leeward Islands, McCann, Septentrional, Sombrero, Mona Channel, Muertos Trough, North Platform, Puerto Rico Trench, Puerto Rico West to Southeast. These scenarios were supplied by Dr. Victor Huerfano, PI of the Puerto Rico Component of NTHMP and Director of the Puerto Rico Seismic Network. These were augmented by eight additional ones corresponding approximately to historical earthquakes. And, finally, a so-called FEMA Catastrophic Tsunami Scenario was added, for a total of 321 events.

RESULTS

Due to the number of tsunami scenarios (see Figure 9), and the large number of different types of outputs, it is not possible to present individual results. These have been stored in an external hard disk, and it contains about 14 compressed TB. For each region, plus the eight extra faults, plus the FEMA scenario, we will present a table showing the fault parameters for each one of the events in the region, followed by a figure showing the inland flooding due to the **Maximum of the Maximum** (**MOM**) for each region, extra faults, and FEMA. Then, finally, these results will be collapsed into a single figure showing the MOM of the MOM’s.

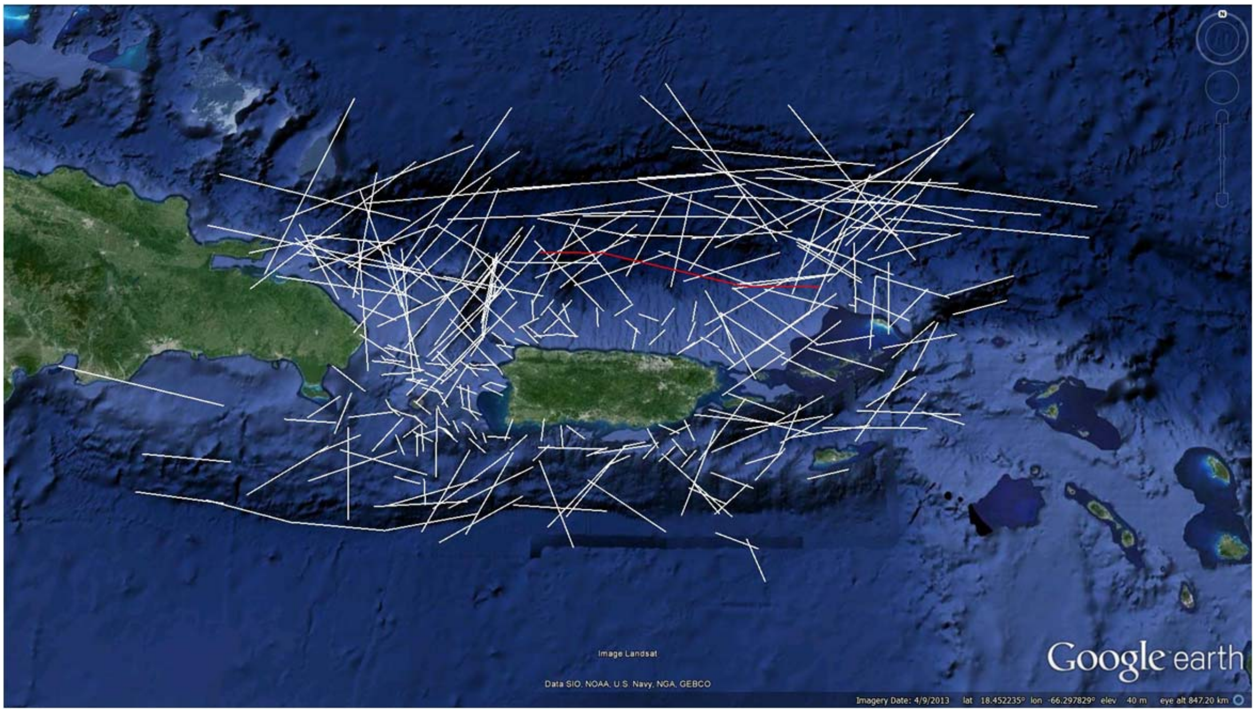

Figure 9 – Ensemble of local tsunami scenarios used to prepare the tsunami flood maps for local sources. The red line shows the FEMA Catastrophic Scenario.

The Mw magnitudes shown in the following tables were computed with the following Matlab script:

```
% Hanks & Kanamori relationship
% 1 gigapascal = 10**9 pascals; 1 pascal = 10 dyne/cm**2
mu = 42 ; % shear modulus in gigapascals

%*******************************************************
L = 53 ; % fault length, in km
W = 20 ; % fault width
u_average = 1.7 ; % average slip, in meters

%scalar seismic moment in dyne-cm [10^(-7) Nm]
Mo = (mu*10^10)*(L*10^5)*(W*10^5)*(u_average*10^2)
%moment magnitude
Mw = (2/3)*log10(Mo) - 10.7
```

Next we present MOM some results for each of the 12 regions. The fault origin (Longitude and Latitude columns) for Victor Huerfano's faults is given following Aki-Richards notation, that is, what is given is the left corner of the upper side of the fault plane. The algorithm that we included in MOST would then compute the coordinates of the middle of the lower border of the fault plane (see Figure 8) by using the switch 1.

LOCAL SCENARIOS BASED ON VICTOR HUERFANO SCENARIOS (from 2003)

Fault: 19°N

Fault	Longitude (°)	Latitude (°)	Length (km)	Width (km)	Dip (°)	Rake (°)	Strike (°)	Slip (m)	Depth (km)	Mw	End Point (°)
1	-65.867	19.033	84.700	33.884	60	-135	72	2.30	4.0	7.6	-65.100 19.268
2	-66.724	18.991	84.700	33.884	75	-135	69	2.30	4.0	7.6	-65.971 19.264
3	-66.289	19.595	84.700	33.884	45	-30	238	2.30	4.0	7.6	-66.974 19.191
4	-66.232	19.483	84.700	33.884	45	-30	228	2.30	4.0	7.6	-66.832 18.973
5	-67.034	19.525	84.700	33.884	45	-135	101	2.30	4.0	7.6	-66.241 19.380
6	-66.373	19.398	84.700	33.884	45	-135	91	2.30	4.0	7.6	-65.566 19.385
7	-65.951	19.746	84.700	33.884	45	-40	207	2.30	4.0	7.6	-66.318 19.067
8	-65.797	19.735	84.700	33.884	45	-30	192	2.30	4.0	7.6	-65.965 18.990
9	-67.034	19.047	84.700	33.800	47	167	66	2.30	4.0	7.6	-66.297 19.357
10	-65.825	19.117	84.700	33.800	45	155	35	2.30	4.0	7.6	-65.362 19.741
11	-64.995	19.441	84.700	33.800	60	56	265	2.30	4.0	7.6	-65.800 19.375
12	-66.696	19.525	84.700	33.800	84	-65	206	2.30	4.0	7.6	-67.050 18.840
13	-67.048	19.342	84.700	33.800	7	-75	136	2.30	4.0	7.6	-66.488 18.794
14	-66.767	19.455	84.700	33.800	10	-80	142	2.30	4.0	7.6	-66.271 18.855
15	-66.064	19.272	84.700	33.800	18	-137	**111**	2.30	4.0	7.6	-65.311 18.999

15 events

Figure 10 – Sources for tsunami scenarios for 19°N.

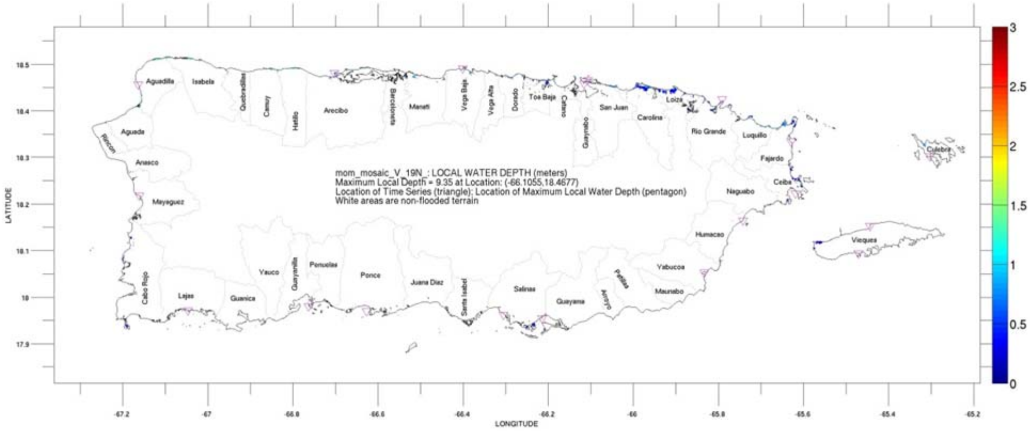

Figure 11 - 19° N MOM

Fault: Anegada Passage

Fault	Longitude (°)	Latitude (°)	Length (km)	Width (km)	Dip (°)	Rake (°)	Strike (°)	Slip (m)	Depth (km)	Mw	End Point (°)
1	-64.349	19.089	63.000	29.016	45	-130	107	2.03	4.0	7.4	-63.776 18.923
2	-63.238	19.103	63.000	29.016	60	-84	253	2.03	4.0	7.4	-63.811 18.937
3	-63.759	18.794	48.000	32.854	30	-101	75	4.8	4.0	7.6	-63.318 18.906
4	-64.236	19.202	63.300	29.016	70	-90	184	2.02	4.0	7.4	-64.278 18.634
5	-64.532	18.921	49.000	32.184	45	-130	114	4.8	4.0	7.6	-64.107 18.742
6	-64.391	18.626	49.000	32.184	60	81	260	4.8	4.0	7.6	-64.849 18.550
7	-63.941	18.991	49.000	32.184	45	-90	226	4.8	4.0	7.6	-64.276 18.685
8	-64.265	18.457	49.000	32.184	25	-160	50	4.8	4.0	7.6	-63.909 18.740
9	-64.489	18.092	49.000	32.184	15	-171	59	4.8	4.0	7.6	-64.091 18.319
10	-65.180	17.715	48.000	32.800	60	-10	25	4.8	4.0	7.6	-64.988 18.106
11	-64.588	17.839	84.000	20.679	85	0	314	3.9	4.0	7.6	-64.160 18.364
12	-64.560	18.064	84.000	20.679	85	0	92	3.9	4.0	7.6	-63.766 18.038
13	-64.827	17.938	84.000	20.679	85	0	90	3.9	4.0	7.6	-64.033 17.938
14	-65.684	18.064	84.000	34.167	23	-174	103	3.9	4.0	7.7	-64.910 17.894
15	-65.670	17.755	49.000	32.184	65	-20	67	4.8	4.0	7.6	-65.244 17.927
16	-65.150	17.825	49.000	32.184	60	-10	61	4.8	4.0	7.6	-64.745 18.039
17	-64.813	18.022	64.000	28.563	45	95	260	2.0	4.0	7.4	-65.409 17.922
18	-65.066	17.867	64.000	28.563	15	-10	81	2.0	4.0	7.4	-64.469 17.957
19	-65.192	17.966	64.000	28.563	15	-160	276	2.0	4.0	7.4	-65.794 18.026
20	-64.335	18.359	64.000	28.563	45	85	287	2.0	4.0	7.4	-64.915 18.527
21	-65.110	18.036	48.000	32.800	70	153	290	4.8	4.0	7.6	-65.537 18.184
22	-65.403	18.148	63.000	29.000	42	104	217	2.0	4.0	7.4	-65.761 17.696
23	-64.110	18.359	48.000	32.800	38	-48	30	4.8	4.0	7.6	-63.882 18.733
24	-63.744	18.640	63.000	29.000	89	-86	259	2.0	4.0	7.4	-64.331 18.532
25	-64.711	18.279	48.000	32.800	47	12	295	4.8	4.0	7.6	-65.123 18.461
26	-65.092	18.493	63.000	29.000	66	-72	235	2.0	4.0	7.4	-65.581 18.168

27	-64.644	18.738	63.000	29.000	79	123	233	2.0	4.0	7.4	-65.121 18.397
28	-64.433	18.524	63.000	29.000	84	52	8	2.0	4.0	7.4	-64.350 19.085

28 events

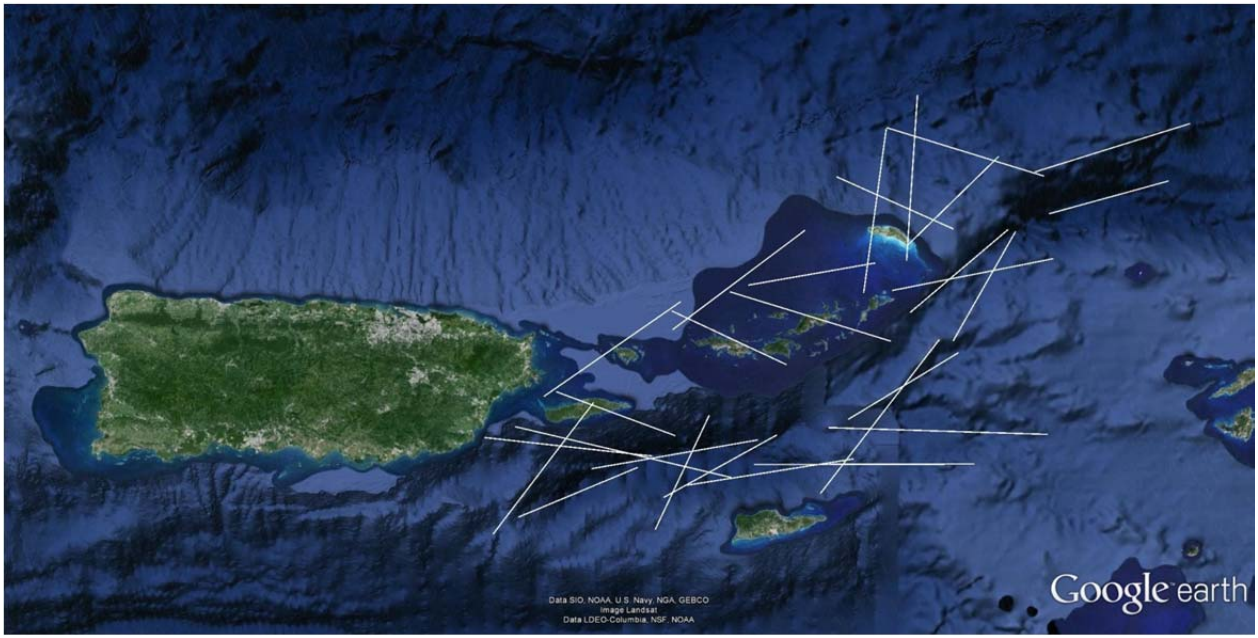

Figure 12 – Sources for tsunami scenarios for Anegada Passage.

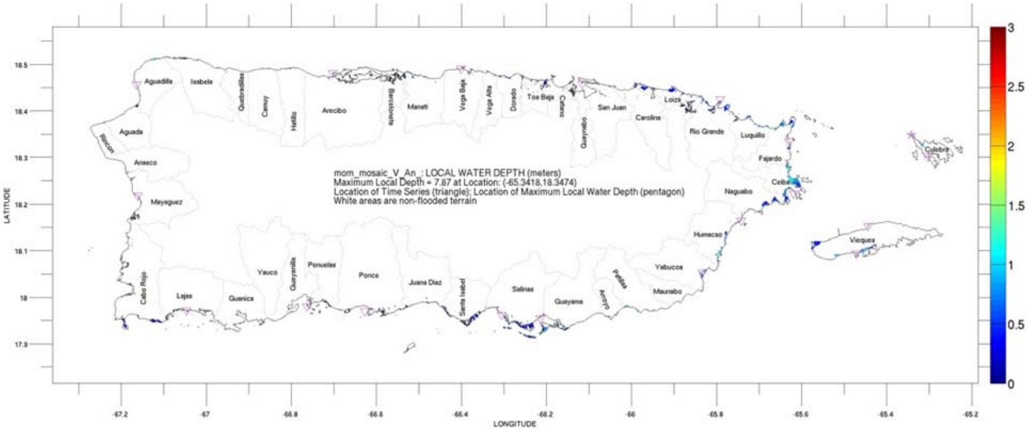

Figure 13 – Anegada Passage's MOM.

Fault: Eastern Dominican Republic

Fault	Longitude (°)	Latitude (°)	Length (km)	Width (km)	Dip (°)	Rake (°)	Strike (°)	Slip (m)	Depth (km)	Mw	End point (°)
1	-67.989	17.980	35.400	20.900	62	89	220	1.50	4.0	7.1	-68.204 17.736
2	-68.481	18.134	30.900	23.900	85	-70	234	2.10	4.0	7.1	-68.718 17.971
3	-68.074	18.022	35.400	20.900	80	126	262	1.50	4.0	7.1	-68.406 17.978
4	-68.397	18.162	35.400	20.900	85	95	198	1.50	4.0	7.1	-68.500 17.859
5	-68.566	18.359	35.400	20.900	20	-85	126	1.50	4.0	7.1	-68.295 18.172
6	-68.088	18.429	35.400	20.900	55	177	302	1.50	4.0	7.1	-68.373 18.598
7	-68.411	18.823	35.400	20.900	65	-83	111	1.50	4.0	7.1	-68.097 18.709
8	-68.495	17.938	42.600	17.800	19	0	273	1.50	4.0	7.4	-68.897 17.958
9	-68.299	17.853	35.400	20.900	60	-103	246	1.50	4.0	7.1	-68.604 17.724

9 events

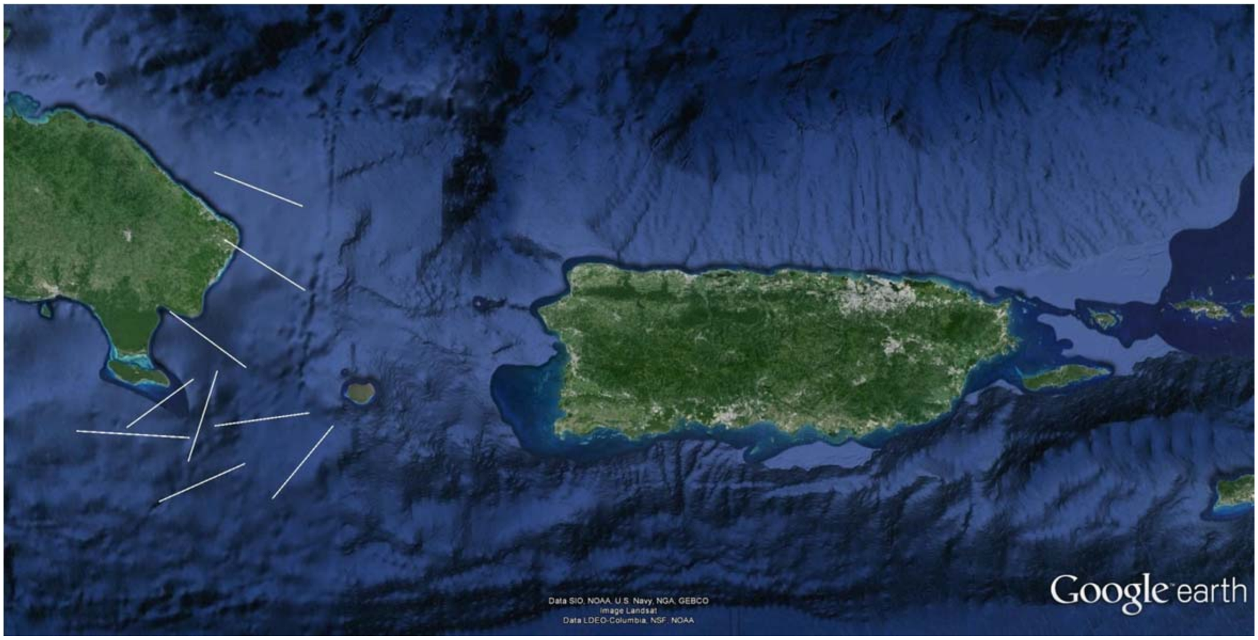

Figure 14 - Sources for tsunami scenarios for Eastern Dominican Republic.

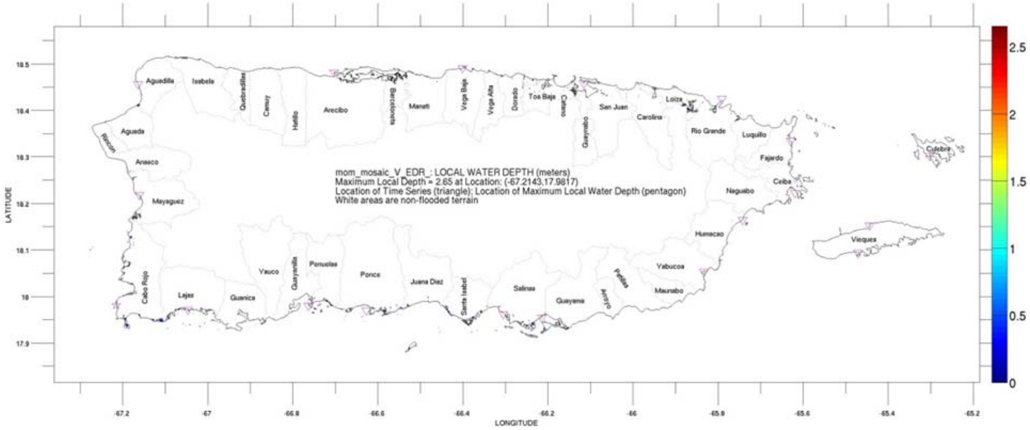

Figure 15 – Eastern Dominican Republic's MOM.

Fault :Leeward Islands

Fault	Longitude (°)	Latitude (°)	Length (km)	Width (km)	Dip (°)	Rake (°)	Strike (°)	Slip (m)	Depth (km)	Mw	End point (°)
1	-64.236	17.952	35.400	20.900	5	5	40	1.50	4.0	7.1	-64.021 18.196
2	-63.744	17.966	35.400	20.900	85	94	287	1.50	4.0	7.1	-64.064 18.059
3	-65.614	17.320	30.900	23.900	84	-86	320	2.10	4.0	7.2	-65.801 17.533
4	-65.839	17.502	30.900	23.900	7	-124	113	2.10	4.0	7.2	-65.571 17.393
5	-65.333	17.081	35.400	20.900	13	-119	290	1.50	4.0	7.1	-65.646 17.190
6	-65.420	17.150	35.400	20.900	85	88	157	1.50	4.0	7.1	-65.290 16.857
7	-65.347	17.558	35.400	20.900	5	26	44	1.50	4.0	7.1	-65.115 17.787
8	-64.644	17.460	35.400	20.900	78	-112	290	1.50	4.0	7.1	-64.958 17.569
9	-65.403	17.530	35.400	20.900	56	-138	228	1.50	4.0	7.1	-65.651 17.317
10	-65.361	17.502	35.400	20.900	56	-132	290	1.50	4.0	7.1	-65.675 17.611
11	-65.136	17.755	30.900	23.900	76	91	253	1.50	4.0	7.1	-65.415 17.674

11 events

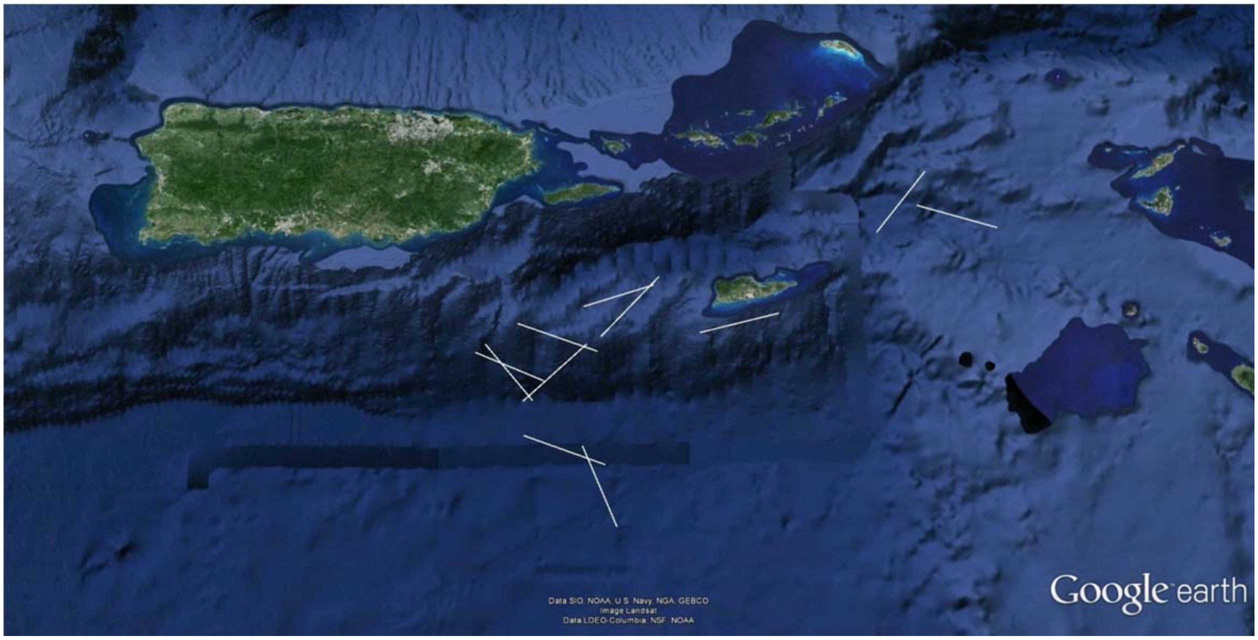

Figure 16 - Sources for tsunami scenarios for Leeward Islands.

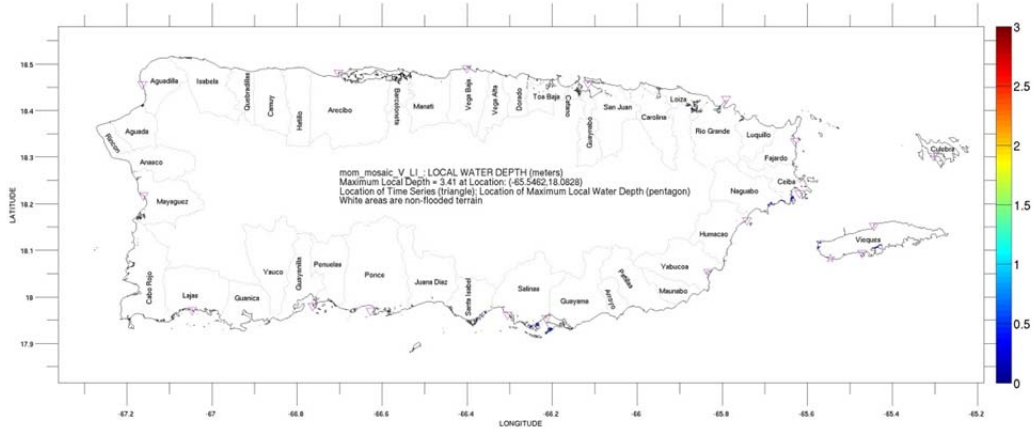

Figure 17 – Leeward Islands' MOM.

Fault: McCann

Fault	Longitude (°)	Latitude (°)	Length (km)	Width (km)	Dip (°)	Rake (°)	Strike (°)	Slip (m)	Depth (km)	Mw	End point (°)
F1918-01	-67.340	19.000	13.000	23.000	85	-95	185	4.0	4.0	7.1	-67.351 18.884
F1918-02	-67.350	18.880	4.000	23.000	34	-146	236	4.0	4.0	6.8	-67.382 18.860
F1918-03	-67.380	18.860	31.000	23.000	82	-98	188	4.0	4.0	7.4	-67.411 18.583
F1918-04	-67.420	18.580	18.000	23.000	60	-120	210	4.0	4.0	7.2	-67.505 18.440
F01-S1	-67.340	19.000	13.000	23.000	85	-95	185	4.0	4.0	7.1	-67.351 18.884
F01-S2	-67.350	18.880	4.000	23.000	34	-146	236	4.0	4.0	6.8	-67.382 18.860
F01-S3	-67.380	18.860	31.000	23.000	82	-98	188	4.0	4.0	7.4	-67.411 18.583
F01-S4	-67.420	18.580	18.000	23.000	60	-120	210	4.0	4.0	7.2	-67.505 18.440
F02-S1	-67.845	18.845	9.384	28.000	63	-137	247	0.58	4.0	6.5	-67.927 18.812
F02-S2	-67.927	18.812	16.020	28.000	63	-129	241	0.58	4.0	6.7	-68.060 18.742
F03-S1	-68.151	18.519	15.924	28.000	63	-139	111	0.64	4.0	6.7	-68.010 18.468
F03-S2	-68.010	18.468	11.978	28.000	63	-143	108	0.64	4.0	6.6	-67.902 18.435
F04-S1	-68.175	18.500	18.000	28.000	63	-149	101	0.68	4.0	6.7	-68.008 18.469
F04-S2	-68.010	18.468	12.000	28.000	63	-143	107	0.68	4.0	6.6	-67.901 18.436
F05-S1	-68.196	18.442	6.000	28.000	63	-113	137	0.48	4.0	6.3	-68.157 18.403
F05-S2	-68.154	18.410	16.000	28.000	63	-153	97	0.48	4.0	6.6	-68.004 18.393
F06-S1	-68.260	18.398	18.000	28.000	63	-154	95	1.01	4.0	6.9	-68.090 18.384
F06-S2	-68.088	18.383	9.000	28.000	63	-144	106	1.01	4.0	6.7	-68.006 18.361
F06-S3	-68.030	18.358	16.000	28.000	63	-150	100	1.01	4.0	6.8	-67.854 18.333
F07-S1	-68.178	18.295	8.000	28.000	63	-163	82	0.80	4.0	6.6	-68.103 18.305
F07-S2	-68.107	18.304	15.000	28.000	63	-160	87	0.80	4.0	6.7	-67.965 18.311
F07-S3	-67.960	18.311	5.000	28.000	63	-169	71	0.80	4.0	6.4	-67.915 18.326
F07-S4	-67.912	18.328	6.000	28.000	63	-161	85	0.80	4.0	6.5	-67.855 18.333
F08-S1	-67.823	18.260	9.000	28.000	63	-160	267	0.40	4.0	6.4	-67.908 18.256
F08-S2	-67.912	18.265	8.000	28.000	63	-159	268	0.40	4.0	6.4	-67.988 18.263

F09-S1	-67.991	18.267	9.000	28.000	63	-145	105	1.31	4.0	6.7	-67.909 18.246
F09-S2	-67.912	18.246	12.000	28.000	63	-144	106	1.31	4.0	6.8	-67.814 18.216
F09-S3	-67.800	18.214	7.000	28.000	63	-128	119	1.31	4.0	6.7	-67.742 18.184
F09-S4	-67.740	18.181	16.000	28.000	63	-73	146	1.31	4.0	6.9	-67.655 18.062
F09-S5	-67.610	17.967	11.000	28.000	63	-59	153	1.31	4.0	6.8	-67.563 17.879
F10-S1	-68.130	18.111	8.000	28.000	63	-68	149	0.40	4.0	6.4	-68.091 18.049
F10-S2	-68.091	18.049	10.000	28.000	63	-114	127	0.40	4.0	6.4	-68.016 17.995
F11-S1	-68.091	18.049	8.000	28.000	63	-137	112	0.81	4.0	6.6	-68.021 18.022
F11-S2	-68.019	18.019	12.000	28.000	63	-145	105	0.81	4.0	6.7	-67.909 17.991
F11-S3	-67.906	17.990	14.000	28.000	63	-112	128	0.81	4.0	6.7	-67.802 17.913
F12-S1	-67.906	17.999	9.000	28.000	63	-99	134	1.21	4.0	6.7	-67.845 17.943
F12-S2	-67.847	17.934	22.000	28.000	63	-34	172	1.21	4.0	7.0	-67.818 17.738
F12-S3	-67.800	17.547	21.000	28.000	63	-32	174	1.21	4.0	7.0	-67.779 17.359
F13-S1	-68.025	17.559	8.000	28.000	63	-143	107	0.49	4.0	6.4	-67.953 17.538
F13-S2	-67.955	17.538	14.000	28.000	63	-147	103	0.49	4.0	6.6	-67.826 17.510
F14-S1	-67.738	18.056	15.000	28.000	63	-30	176	1.31	4.0	6.9	-67.728 17.921
F14-S2	-67.729	17.921	22.000	28.000	63	-29	178	1.31	4.0	7.0	-67.723 17.723
F14-S3	-67.721	17.728	19.000	28.000	63	-30	177	1.31	4.0	6.9	-67.712 17.557
F15-S1	-67.635	17.931	14.000	28.000	63	-81	322	0.44	4.0	6.5	-67.717 18.030
F15-S2	-67.716	18.034	5.000	28.000	63	-55	336	0.44	4.0	6.2	-67.735 18.075
F16-S1	-67.605	17.852	8.000	28.000	63	-102	312	0.35	4.0	6.3	-67.661 17.900
F16-S2	-67.659	17.901	8.000	28.000	63	-144	286	0.35	4.0	6.3	-67.732 17.921
F17-S1	-67.424	17.830	11.000	28.000	63	-72	326	0.41	4.0	6.4	-67.482 17.912
F17-S2	-67.479	17.912	8.000	28.000	63	-115	306	0.41	4.0	6.4	-67.541 17.954
F18-S1	-67.511	18.225	15.000	28.000	63	-32	174	0.48	4.0	6.6	-67.496 18.091
F18-S2	-67.498	18.094	7.000	28.000	63	-38	168	0.48	4.0	6.4	-67.484 18.032
F18-S3	-67.485	18.034	10.000	28.000	63	-96	135	0.48	4.0	6.5	-67.418 17.970

F18-S4	-67.382	17.882	9.000	28.000	63	-50	159	0.48	4.0	6.4	-67.352 17.806
F19-S1	-67.420	18.767	23.000	28.000	63	-68	180	0.53	4.0	6.7	-67.420 18.560
F20-S1	-67.360	19.000	19.000	28.000	63	-63	187	0.43	4.0	6.6	-67.382 18.830
F21-S1	-67.280	19.000	22.0000	28.000	63	-35	210	0.49	4.0	6.7	-67.385 18.829
F22-S1	-67.170	18.580	13.000	28.000	63	-101	114	0.63	4.0	6.6	-67.057 18.532
F22-S2	-67.310	18.530	15.000	28.000	63	-111	98	0.63	4.0	6.7	-67.169 18.511
F23-S1	-67.310	18.530	18.000	28.000	63	-94	130	0.41	4.0	6.6	-67.179 18.426
F24-S1	-67.510	18.390	4.000	28.000	63	-97	124	0.86	4.0	6.4	-67.479 18.370
F24-S2	-67.480	18.370	5.000	28.000	63	-127	79	0.86	4.0	6.4	-67.434 18.379
F24-S3	-67.430	18.380	11.000	28.000	63	-117	90	0.86	4.0	6.7	-67.326 18.380
F24-S4	-67.330	18.380	6.000	28.000	63	-98	121	0.86	4.0	6.5	-67.281 18.352
F24-S5	-67.280	18.350	6.000	28.000	63	-265	149	0.86	4.0	6.5	-67.251 18.304
F25-S1	-67.360	19.110	23.000	28.000	63	-250	357	0.53	4.0	6.7	-67.372 19.204
F26-S1	-67.400	18.220	7.000	28.000	63	-149	63	0.46	4.0	6.4	-67.341 18.249
F26-S2	-67.340	18.250	13.000	28.000	63	-104	108	0.46	4.0	6.5	-67.223 18.214
F27-S1	-67.590	18.410	12.000	28.000	63	-97	124	0.47	4.0	6.5	-67.496 18.350
F27-S2	-67.500	18.350	9.000	28.000	63	-91	135	0.47	4.0	6.4	-67.440 18.293
F28-S1	-67.610	18.340	3.000	28.000	63	-91	315	0.50	4.0	6.1	-67.630 18.359
F28-S2	-67.630	18.360	19.000	28.000	63	-92	313	0.50	4.0	6.7	-67.762 18.477
F29-S1	-67.640	18.330	5.000	28.000	63	-100	297	0.40	4.0	6.2	-67.682 18.350
F29-S2	-67.680	18.350	13.000	28.000	63	-270	318	0.40	4.0	6.5	-67.762 18.437
F30-S1	-67.115	18.667	19.000	28.000	63	-91	136	0.42	4.0	6.6	-66.990 18.544
F31-S1	-67.350	18.625	12.000	28.000	63	-275	126	0.39	4.0	6.5	-67.258 18.562
F31-S2	-67.258	18.558	5.000	28.000	63	-265	149	0.39	4.0	6.2	-67.234 18.520

76 events

Figure 1 - Sources for tsunami scenarios for McCann.

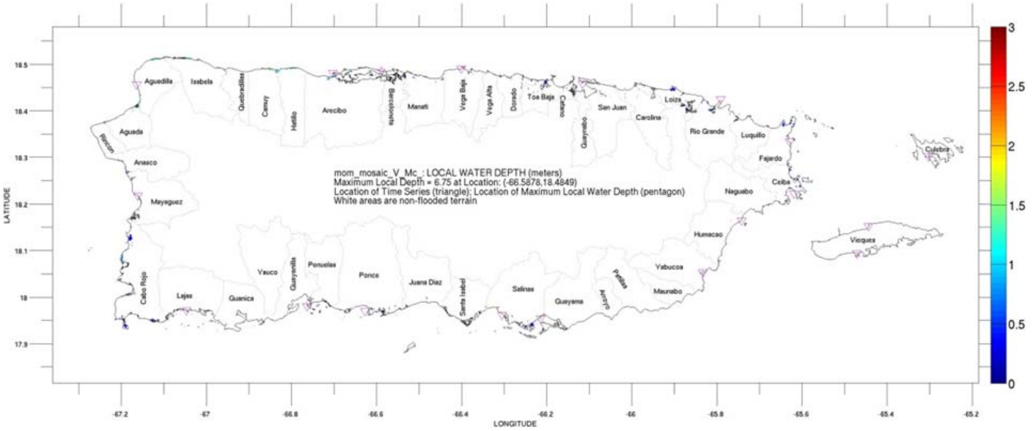

Figure 19 – McCann's MOM.

Fault: Septentrional

Fault	Longitude (°)	Latitude (°)	Length (km)	Width (km)	Dip (°)	Rake (°)	Strike (°)	Slip (m)	Depth (km)	Mw	End point (°)
1	-68.156	19.312	77.600	39.800	45	-160	275	5.00	4.0	7.8	-68.893 19.373
2	-68.945	19.462	77.000	43.597	65	85	149	11.01	4.0	8.1	-68.567 18.868
3	-68.407	18.907	77.000	39.800	25	100	310	2.60	4.0	7.6	-68.969 19.352
4	-68.453	19.328	113.000	39.894	85	105	171	2.64	4.0	7.8	-68.285 18.324
5	-68.102	19.272	113.000	39.894	45	-60	171	2.64	4.0	7.8	-67.934 18.268
6	-68.453	18.879	113.000	39.894	52	-117	5	2.64	4.0	7.8	-68.359 19.891
7	-68.214	19.286	113.000	39.894	65	-88	162	2.64	4.0	7.8	-67.882 18.320
8	-68.060	18.808	113.000	39.894	25	-95	337	2.64	4.0	7.8	-68.481 19.743
9	-68.819	19.089	113.000	39.894	85	180	68	2.64	4.0	7.8	-67.821 19.470
10	-68.945	19.230	113.000	39.894	85	180	99	2.64	4.0	7.8	-67.883 19.071
11	-69.087	19.043	113.200	39.894	30	-91	98	2.64	4.0	7.8	-68.021 18.901
12	-68.850	19.316	113.200	39.894	34	-96	118	2.64	4.0	7.8	-67.899 18.838
13	-68.608	19.384	77.600	39.894	80	-90	257	2.64	4.0	7.7	-69.329 19.227
14	-68.397	19.342	77.600	39.894	49	74	125	2.64	4.0	7.7	-67.792 18.942

14 events

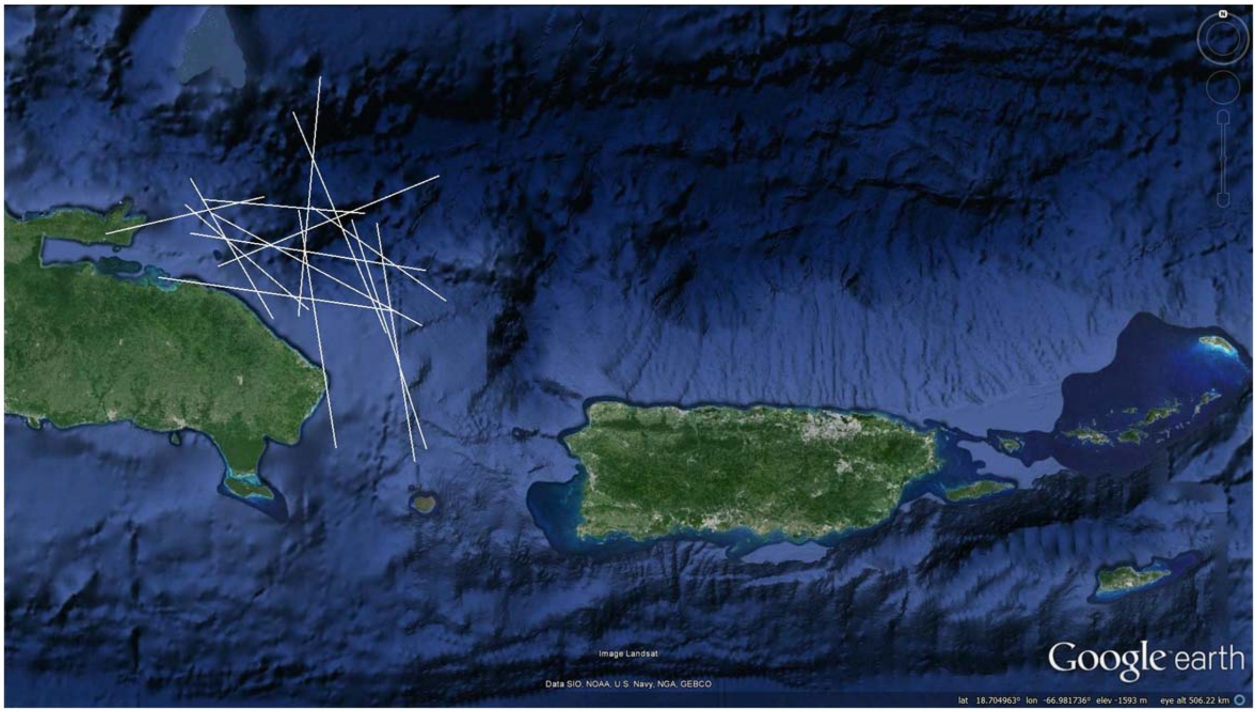

Figure 20 - Sources for tsunami scenarios for Septentrional.

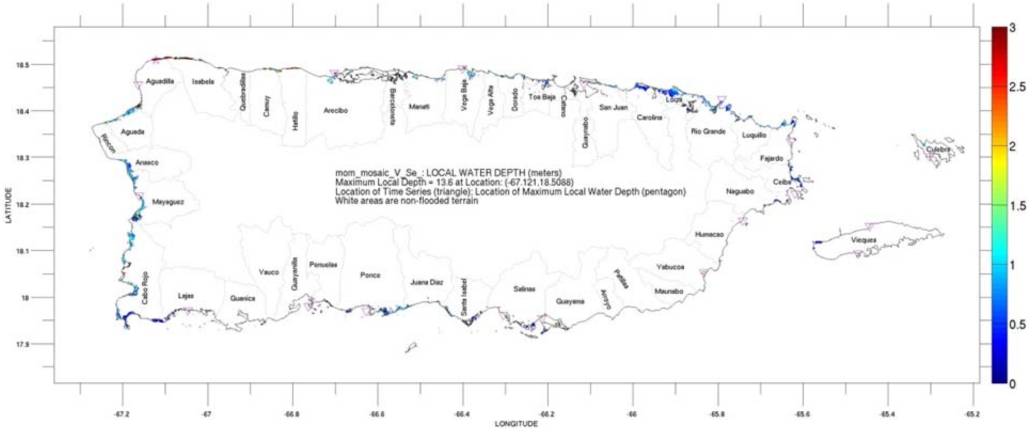

Figure 21 – Septentrional's MOM.

Fault:Sombrero

Fault	Longitude (°)	Latitude (°)	Length (km)	Width (km)	Dip (°)	Rake (°)	Strike (°)	Slip (m)	Depth (km)	Mw	End point (°)
1	-64.405	19.216	84.700	33.884	80	86	73	2.30	4.0	7.6	-63.633 19.439
2	-63.716	19.426	84.700	33.884	10	111	274	2.30	4.0	7.6	-64.522 19.479
3	-64.335	19.286	84.700	33.884	80	86	38	2.30	4.0	7.6	-63.837 19.886
4	-63.969	19.750	84.700	33.884	10	111	239	2.30	4.0	7.6	-64.662 19.358
5	-64.967	19.356	62.000	37.113	80	90	122	7.30	4.0	7.9	-64.466 19.061
6	-64.461	19.033	62.000	37.113	10	89	302	7.30	4.0	7.9	-64.962 19.329
7	-64.714	19.244	84.700	33.884	75	110	28	2.30	4.0	7.6	-64.334 19.917
8	-65.698	18.963	84.700	33.884	5	45	152	2.30	4.0	7.6	-65.321 18.290
9	-65.010	19.075	84.700	33.884	15	-90	240	2.30	4.0	7.6	-65.707 18.694
10	-65.586	18.794	62.000	37.113	85	90	124	7.30	4.0	7.9	-65.098 18.482
11	-65.586	18.794	62.000	37.113	1	-45	169	7.30	4.0	7.9	-65.474 18.482
12	-64.897	18.780	84.700	33.884	80	110	25	2.30	4.0	7.6	-64.556 19.470
13	-64.504	19.356	62.000	37.113	80	45	182	7.30	4.0	7.9	-64.525 18.799
14	-64.518	18.851	62.000	37.113	45	-166	281	7.30	4.0	7.9	-64.576 18.862
15	-65.319	18.500	84.700	33.884	60	90	54	2.30	4.0	7.6	-64.668 18.948
16	-64.883	18.808	84.700	33.884	30	90	234	2.30	4.0	7.6	-65.533 18.360
17	-65.234	18.977	62.000	37.113	85	-160	105	7.30	4.0	7.9	-64.665 18.833
18	-65.487	18.977	84.700	33.884	18	92	81	2.30	4.0	7.6	64.691 19.096
19	-64.672	19.103	84.700	33.884	72	89	263	2.30	4.0	7.6	-65.472 19.010
20	-65.487	18.987	84.700	33.884	16	23	125	2.30	4.0	7.6	-64.828 18.550
21	-64.953	19.384	84.700	33.884	45	-162	112	2.30	4.0	7.6	-64.205 19.099
22	-64.151	19.569	84.700	33.884	86	93	226	2.30	4.0	7.6	-64.732 19.040
23	-64.925	19.300	84.700	33.884	85	87	54	2.30	4.0	7.6	-64.271 19.748
24	-64.728	19.651	84.700	33.884	76	-82	201	2.30	4.0	7.6	-65.017 18.940

24 events

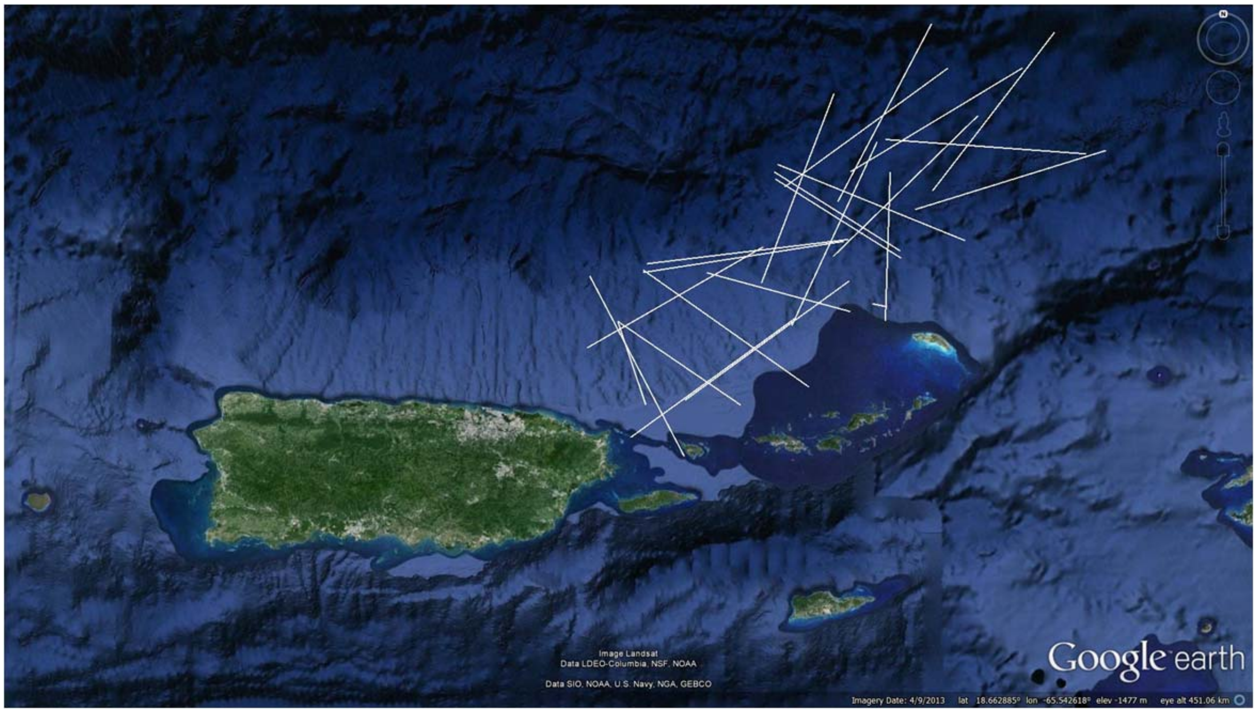

Figure 22 - Sources for tsunami scenarios for Sombrero.

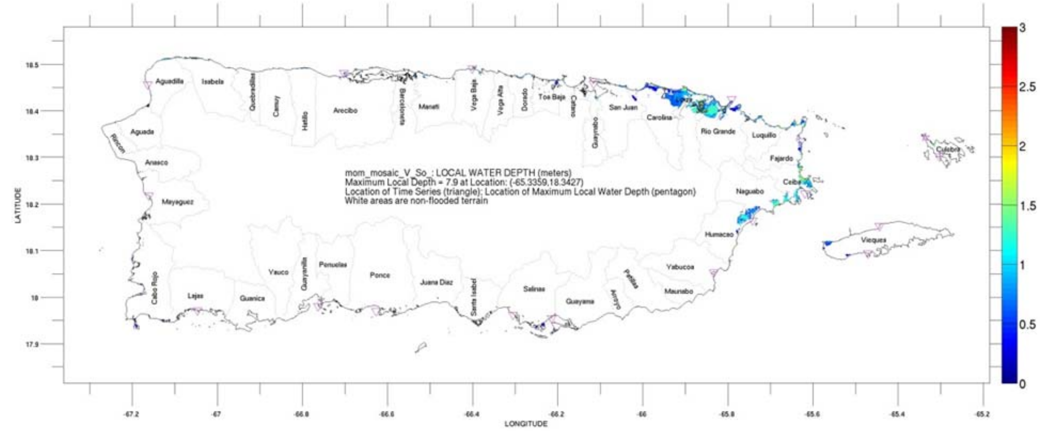

Figure 23 – Sombrero's MOM.

Fault: Mona Channel

Fault	Longitude (°)	Latitude (°)	Length (km)	Width (km)	Dip (°)	Rake (°)	Strike (°)	Slip (m)	Depth (km)	Mw	End point (°)
1	-67.146	19.455	62.000	37.113	60	-90	216	7.30	4.0	7.9	-67.493 19.004
2	-67.512	18.935	62.000	37.113	30	-90	36	7.30	4.0	7.9	-67.165 19.386
3	-67.357	19.764	84.700	33.884	45	-45	198	2.30	4.0	7.6	-67.607 19.040
4	-67.849	19.469	84.700	33.884	45	-90	121	2.30	4.0	7.6	-67.157 19.077
5	-67.413	18.963	84.700	33.884	61	123	283	2.30	4.0	7.6	-68.198 19.134
6	-67.413	18.823	62.000	37.113	45	-90	221	7.30	4.0	7.9	-67.799 18.402
7	-67.793	18.823	62.000	37.113	45	-90	41	7.30	4.0	7.9	-67.406 19.244
8	-67.371	18.668	84.700	33.884	45	-90	221	7.30	4.0	7.9	-67.898 18.093
9	-67.694	18.289	84.700	33.884	45	-90	41	7.30	4.0	7.9	-67.167 18.864
10	-67.343	19.244	62.000	37.113	45	-90	189	7.30	4.0	7.9	-67.435 18.693
11	-67.427	18.654	62.000	37.113	45	-90	9	7.30	4.0	7.9	-67.335 19.205
12	-67.343	19.146	84.000	34.167	58	-81	214	2.30	4.0	7.6	-67.789 18.520
13	-67.287	18.977	84.000	34.167	60	-75	224	2.30	4.0	7.6	-67.841 18.434
14	-66.963	18.907	84.700	34.167	75	10	281	2.30	4.0	7.6	-67.754 19.052
15	-67.680	18.935	61.000	37.721	65	-130	216	2.30	4.0	7.5	-68.020 18.491
16	-67.526	19.005	84.700	34.167	60	-50	243	2.30	4.0	7.6	-68.243 18.659
17	-67.512	19.469	84.700	33.893	60	-35	224	2.30	4.0	7.6	-68.072 18.921
18	-67.357	18.991	61.600	37.360	45	-100	31	7.30	4.0	7.9	-67.055 19.466
19	-67.371	18.854	62.000	37.100	15	-105	40	7.30	4.0	7.9	-66.992 19.281
20	-67.188	18.879	62.000	37.100	17	-97	321	7.30	4.0	7.9	-67.559 19.312
21	-67.174	18.626	62.000	37.100	20	-110	313	7.30	4.0	7.9	-67.605 19.006
22	-67.680	18.724	62.000	37.100	48	-152	135	7.30	4.0	7.9	-67.264 18.330
23	-67.483	18.626	84.700	33.800	48	124	321	2.30	4.0	7.6	-67.990 19.218

23 events

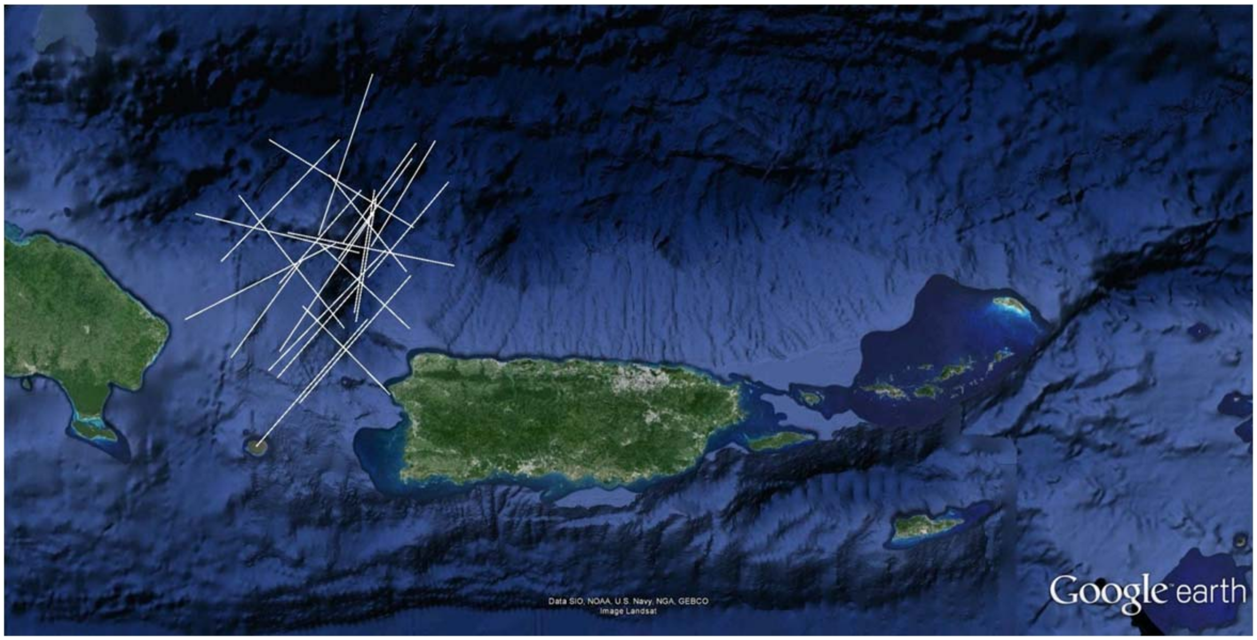

Figure 24 - Sources for tsunami scenarios for Mona Channel.

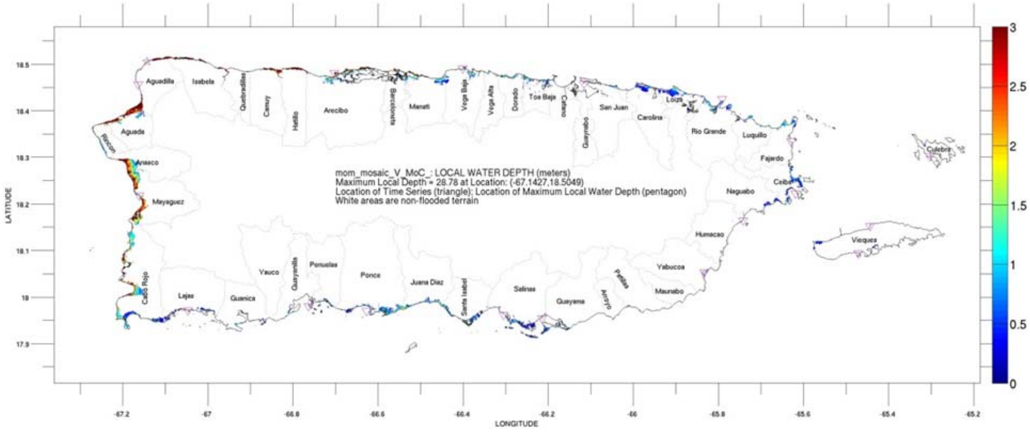

Figure 25 – Mona Channel's MOM.

Fault: Muertos Trough

Fault	Longitude (°)	Latitude (°)	Length (km)	Width (km)	Dip (°)	Rake (°)	Strike (°)	Slip (m)	Depth (km)	Mw	End point (°)
1	-69.283	17.348	73.200	31.200	40	-105	276	2.1	4.0	7.5	-69.969 17.417
2	-69.269	17.643	73.200	31.200	40	-105	274	2.1	4.0	7.5	-69.958 17.689
3	-68.748	17.221	73.200	31.200	41	-88	283	2.1	4.0	7.5	-69.420 17.369
4	-68.018	17.741	73.200	31.200	21	-90	250	2.1	4.0	7.5	-68.667 17.516
5	-68.060	17.179	73.200	31.200	40	-100	274	2.1	4.0	7.5	-68.748 17.225
6	-67.399	17.544	73.200	31.200	68	-95	253	2.1	4.0	7.5	-68.059 17.352
7	-67.469	17.390	73.200	31.200	65	-126	266	2.1	4.0	7.5	-68.157 17.344
8	-67.385	17.306	73.200	31.200	43	-95	259	2.1	4.0	7.5	-68.062 17.180
9	-67.722	17.334	73.200	31.200	89	-118	52	2.1	4.0	7.5	-67.178 17.739
10	-66.991	17.640	73.200	31.200	56	106	243	2.1	4.0	7.5	-67.606 17.341
11	-66.949	17.685	73.200	31.200	71	-103	157	2.1	4.0	7.5	-66.680 17.079
12	-66.443	17.334	73.200	31.200	45	-120	273	2.1	4.0	7.5	-67.132 17.369
13	-66.008	17.193	73.200	31.200	48	60	303	2.1	4.0	7.5	-66.587 17.552
14	-66.738	17.292	73.200	31.200	60	-117	39	2.1	4.0	7.5	-66.304 17.804
15	-66.401	17.699	73.200	31.200	39	-52	223	2.1	4.0	7.5	-66.872 17.218
16	-68.538	17.769	73.200	31.200	45	150	237	2.1	4.0	7.5	-69.117 17.411
17	-68.341	17.250	73.200	31.200	36	-30	355	2.1	4.0	7.5	-68.401 17.906
18	-67.779	17.573	73.200	31.200	80	73	285	2.1	4.0	7.5	-68.446 17.743
19	-67.469	17.755	73.200	31.200	87	-137	208	2.1	4.0	7.5	-67.793 17.174
20	-67.062	17.432	73.200	31.200	40	-120	240	2.1	4.0	7.5	-67.659 17.103
21	-66.036	17.741	73.200	31.200	84	-60	132	2.1	4.0	7.5	-65.523 17.301
22	-65.895	17.307	73.200	31.200	30	169	22	2.1	4.0	7.5	-65.636 17.917
23	-67.146	17.741	73.200	31.200	27	70	208	2.1	4.0	7.5	-67.470 17.160

23 events

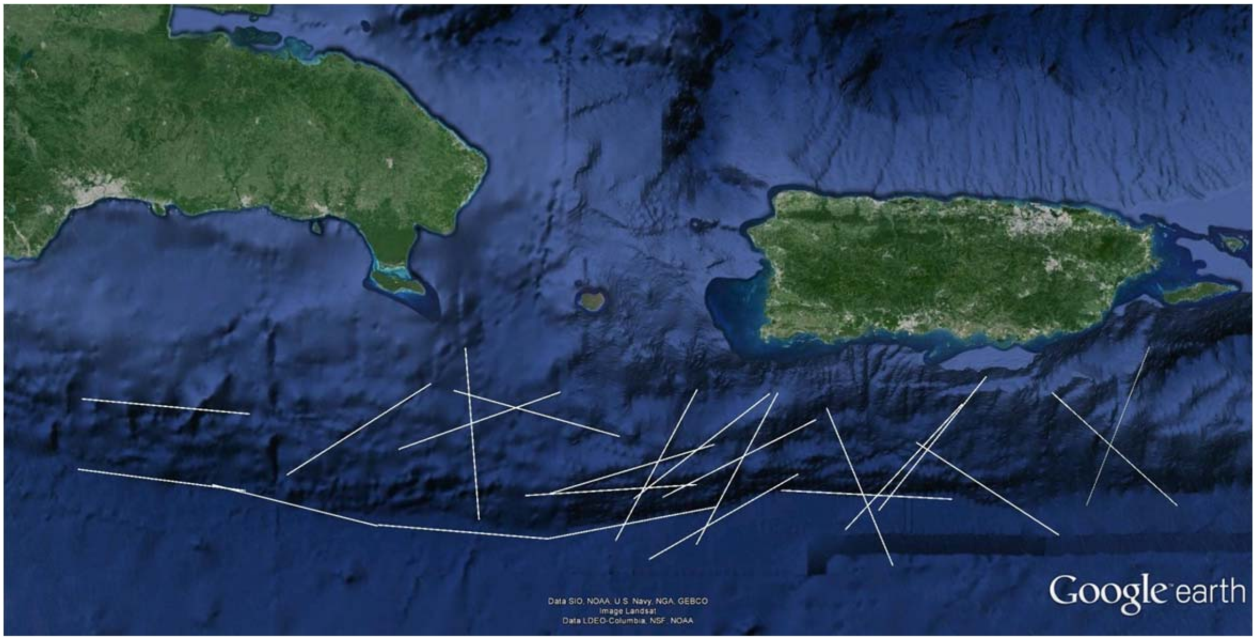

Figure 26 - Sources for tsunami scenarios for Muertos Trough.

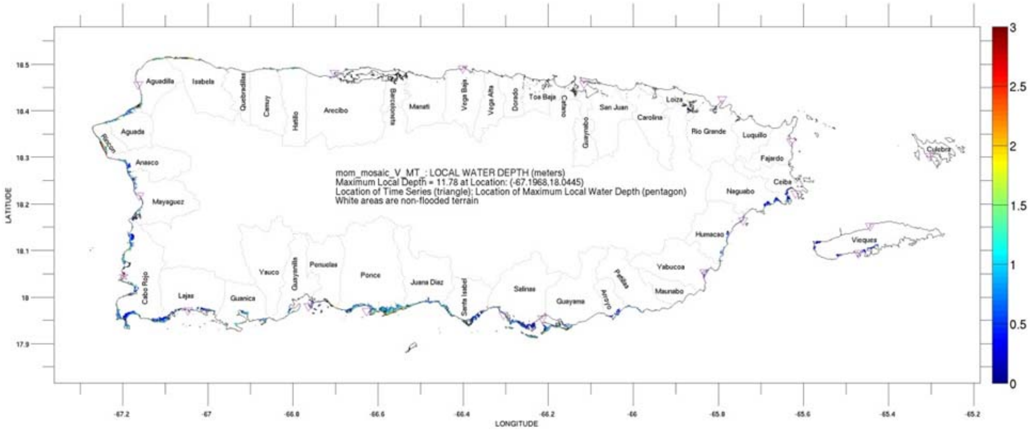

Figure 27 – Muertos Trough's MOM.

Fault: North Platform

Fault	Longitude (°)	Latitude (°)	Length (km)	Width (km)	Dip (°)	Rake (°)	Strike (°)	Slip (m)	Depth (km)	Mw	End point (°)
1	-66.963	18.584	18.000	13.300	30	-155	309	1.10	4.0	6.7	-67.096 18.686
2	-66.682	18.598	18.000	13.300	25	-150	277	1.10	4.0	6.7	-66.852 18.618
3	-66.879	18.879	17.000	13.300	70	100	217	1.10	4.0	6.6	-66.976 18.757
4	-66.738	18.879	17.000	13.300	70	105	219	1.10	4.0	6.6	-66.840 18.760
5	-66.921	18.823	17.000	13.300	30	-160	136	1.10	4.0	6.6	-66.809 18.713
6	-66.809	18.851	17.000	13.300	30	-155	160	1.10	4.0	6.6	-66.754 18.707
7	-66.542	18.823	17.000	13.300	80	-50	176	1.10	4.0	6.6	-66.531 18.671
8	-66.204	18.626	17.000	13.300	50	100	313	1.10	4.0	6.6	-66.322 18.730
9	-66.064	18.724	17.000	13.300	50	105	290	1.10	4.0	6.6	-66.216 18.776
10	-66.261	18.851	18.000	13.200	80	15	236	1.10	4.0	6.7	-66.403 18.761
11	-65.941	18.823	18.000	13.200	75	20	215	1.10	4.0	6.7	-66.039 18.690
12	-66.134	18.542	18.000	13.200	70	-80	45	1.10	4.0	6.7	-66.013 18.657
13	-65.700	18.598	17.000	13.300	25	160	51	1.10	4.0	6.6	-65.575 18.694
14	-65.600	18.528	17.000	13.300	30	100	300	1.10	4.0	6.6	-65.740 18.604
15	-65.712	18.598	17.000	13.300	30	45	237	1.10	4.0	6.6	-65.847 18.515
16	-66.949	18.626	18.000	13.200	71	-138	45	1.10	4.0	6.7	-66.828 18.741
17	-66.809	18.710	18.000	13.200	30	-160	136	1.10	4.0	6.7	-66.690 18.594
18	-66.991	18.738	18.000	13.200	85	-93	242	1.10	4.0	6.7	-67.142 18.662
19	-66.851	18.612	18.000	13.200	25	-150	265	1.10	4.0	6.7	-67.021 18.598
20	-65.839	18.570	18.000	13.200	54	106	21	1.10	4.0	6.7	-65.778 18.721
21	-65.769	18.879	18.000	13.200	38	69	190	1.10	4.0	6.7	-65.799 18.720
22	-66.232	18.668	18.000	13.200	40	-138	190	1.10	4.0	6.7	-66.262 18.509
23	-65.923	18.471	18.000	13.200	85	82	55	1.10	4.0	6.7	-65.783 18.564
24	-65.600	18.514	18.000	13.200	27	76	135	1.10	4.0	6.7	-65.479 18.400
25	-67.048	18.879	18.000	13.200	85	89	175	1.10	4.0	6.7	-67.033 18.718

25 events

Figure 28 - Sources for tsunami scenarios for North Platform.

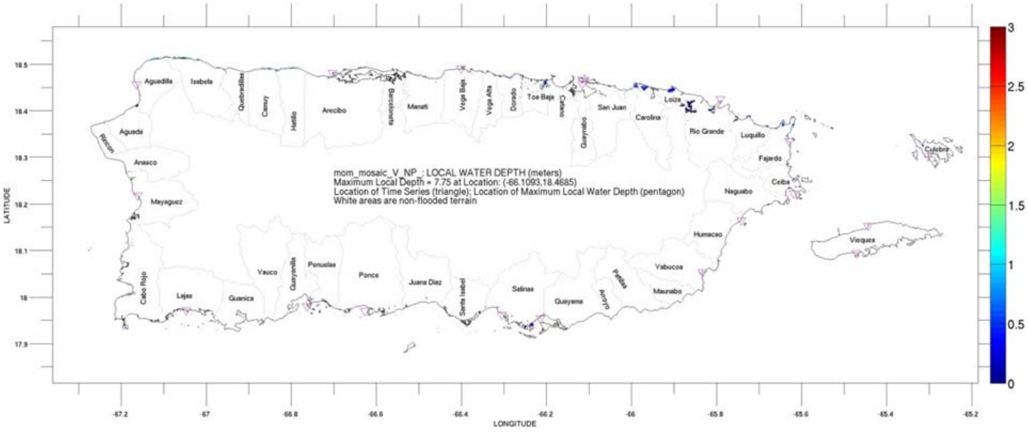

Figure 29 – North Platform’s MOM.

Fault: Puerto Rico Trench

Fault	Longitude (°)	Latitude (°)	Length (km)	Width (km)	Dip (°)	Rake (°)	Strike (°)	Slip (m)	Depth (km)	Mw	End point (°)
1	-64.124	19.862	174.000	50.690	45	-135	97	3.20	4.0	8.0	-62.474 19.672
2	-64.616	19.707	174.000	50.690	45	-135	94	3.20	4.0	8.0	-62.958 19.598
3	-64.236	19.553	174.000	50.690	45	-135	95	3.20	4.0	8.0	-62.582 19.417
4	-65.052	19.483	174.000	50.690	10	86	60	3.20	4.0	8.0	-63.611 20.265
5	-64.124	19.988	174.000	50.690	85	85	244	3.20	4.0	8.0	-65.617 19.302
6	-64.574	19.328	174.000	50.690	10	86	44	3.20	4.0	8.0	-63.418 20.454
7	-63.730	20.157	174.000	50.690	85	85	228	3.20	4.0	8.0	-64.965 19.110
8	-65.277	19.876	174.000	50.690	30	-135	91	3.20	4.0	8.0	-63.614 19.849
9	-65.614	19.721	174.000	50.690	40	-145	92	3.20	4.0	8.0	-63.953 19.666
10	-65.951	20.129	174.000	50.690	40	-140	95	3.20	4.0	8.0	-64.291 19.993
11	-66.993	19.553	174.000	50.690	50	-150	80	3.20	4.0	8.0	-65.356 19.825
12	-66.232	19.862	174.000	50.690	30	-135	85	3.20	4.0	8.0	-64.574 19.998
13	-66.233	19.834	174.000	50.690	40	-120	111	3.20	4.0	8.0	-64.683 19.273
14	-65.122	19.356	174.000	50.690	56	110	328	3.20	4.0	8.0	-66.005 20.683
15	-65.030	19.461	174.900	50.690	56	110	315	3.20	4.0	8.0	-66.214 20.573
16	-67.287	19.764	174.000	50.690	40	-135	85	3.20	4.0	8.0	-65.630 19.900
17	-68.425	19.637	174.000	50.690	45	-160	84	3.20	4.0	8.0	-66.772 19.801
18	-69.662	19.876	174.000	50.690	82	-107	104	3.20	4.0	8.0	-68.049 19.497
19	-67.751	19.511	174.000	50.690	45	-135	87	3.20	4.0	8.0	-66.093 19.593
20	-67.427	19.862	174.000	50.690	63	-75	217	3.20	4.0	8.0	-68.424 18.612
21	-68.115	19.103	174.000	50.690	30	-117	30	3.20	4.0	8.0	-67.284 20.458
22	-68.510	19.117	174.000	50.690	45	-160	52	3.20	4.0	8.0	-67.201 20.080
23	-68.046	19.988	174.000	50.690	45	-55	228	3.20	4.0	8.0	-69.279 18.941
24	-68.608	20.536	174.900	50.690	80	-94	200	3.20	4.0	8.0	-69.180 19.058
25	-67.582	20.129	174.900	50.700	45	-35	246	3.20	4.0	8.0	-69.109 19.489
26	-64.981	20.507	174.900	50.690	45	-90	145	3.20	4.0	8.0	-64.022 19.219

27	-65.706	19.982	174.900	50.700	40	-150	111	3.20	4.0	8.0	-64.146 19.418
28	-65.132	19.946	174.900	50.700	35	-140	105	3.20	4.0	8.0	-63.518 19.539

28 events

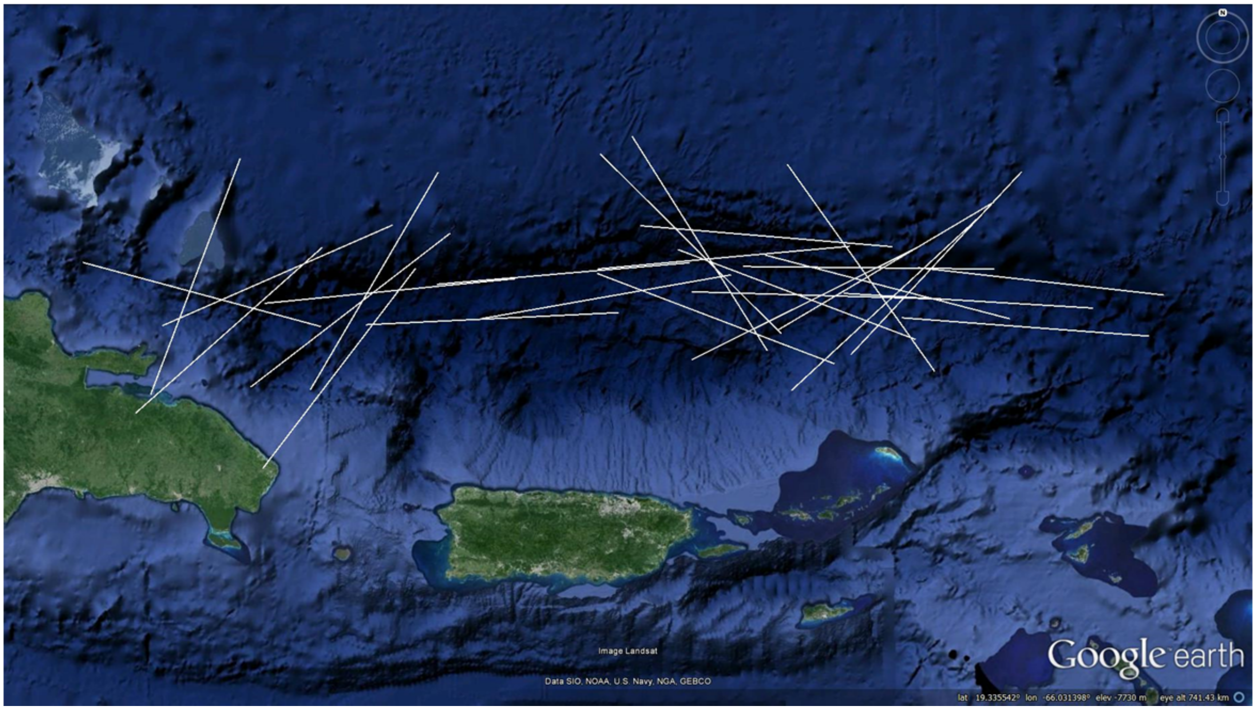

Figure 30 - Sources for tsunami scenarios for Puerto Rico Trench.

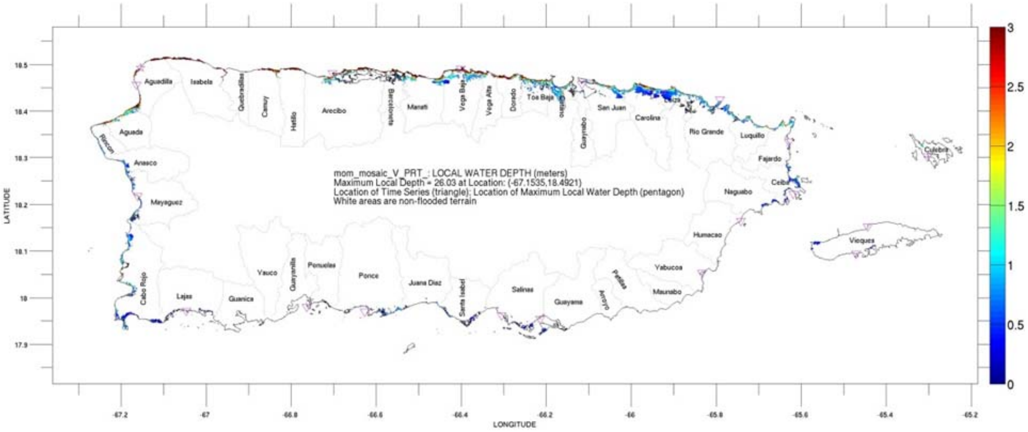

Figure 2 – Puerto Rico Trench's MOM.

Fault: Puerto Rico West to Southeast

Fault	Longitude (°)	Latitude (°)	Length (km)	Width (km)	Dip (°)	Rake (°)	Strike (°)	Slip (m)	Depth (km)	Mw	End point (°)
1	-65.825	17.952	18.000	13.278	45	150	244	1.10	4.0	6.7	-65.978 17.881
2	-66.879	17.797	18.000	13.278	45	160	224	1.10	4.0	6.7	-66.997 17.681
3	-65.783	17.769	18.000	13.278	60	120	221	1.10	4.0	6.7	-65.895 17.647
4	-65.937	17.797	18.000	13.278	60	125	226	1.10	4.0	6.7	-66.059 17.685
5	-66.064	17.825	18.000	13.278	60	120	222	1.10	4.0	6.7	-66.178 17.705
6	-66.795	17.938	18.000	13.278	80	-170	174	1.10	4.0	6.7	-66.777 17.777
7	-66.275	17.727	18.000	13.278	65	120	246	1.10	4.0	6.7	-66.430 17.661
8	-66.148	17.924	18.000	13.278	75	150	151	1.10	4.0	6.7	-66.066 17.781
9	-66.162	17.825	18.000	13.278	70	160	258	1.10	4.0	6.7	-66.328 17.791
10	-66.753	17.938	18.000	13.278	60	15	126	1.10	4.0	6.7	-66.615 17.843
11	-67.048	17.867	18.000	13.278	60	155	226	1.10	4.0	6.7	-67.170 17.755
12	-67.160	17.980	18.000	13.278	65	110	198	1.10	4.0	6.7	-67.213 17.826
13	-67.863	18.205	18.000	13.278	15	170	105	1.10	4.0	6.7	-67.698 18.163
14	-67.849	18.317	18.000	13.278	20	170	113	1.10	4.0	6.7	-67.692 18.254
15	-67.399	18.219	18.000	13.278	60	165	114	1.10	4.0	6.7	-67.243 18.153
16	-67.554	18.064	18.000	13.278	60	160	110	1.10	4.0	6.7	-67.394 18.009
17	-67.849	17.938	18.000	13.278	45	120	231	1.10	4.0	6.7	-67.981 17.836
18	-67.877	17.867	18.000	13.278	60	10	176	1.10	4.0	6.7	-67.865 17.706
19	-67.905	17.882	18.000	13.278	45	-85	116	1.10	4.0	6.7	-67.752 17.811
20	-66.443	17.783	18.000	13.278	75	170	247	1.10	4.0	6.7	-66.600 17.720
21	-66.064	17.952	18.000	13.278	50	-10	113	1.10	4.0	6.7	-65.907 17.889
22	-67.483	17.839	18.000	13.278	45	-120	130	1.10	4.0	6.7	-67.353 17.735
23	-67.526	18.359	18.000	13.278	60	15	97	1.10	4.0	6.7	-67.357 18.339
24	-67.343	17.853	18.000	13.278	45	-75	93	1.10	4.0	6.7	-67.173 17.845
25	-67.849	18.387	18.000	13.278	25	170	95	1.10	4.0	6.7	-67.679 18.373
26	-67.441	18.162	18.000	13.278	36	-46	290	1.10	4.0	6.7	-67.601 18.217

27	-67.724	17.896	18.000	13.278	51	-81	252	1.10	4.0	6.7	-67.886 17.846
28	-66.939	17.825	18.000	13.278	47	-159	5	1.10	4.0	6.7	-66.924 17.986
29	-67.540	18.072	18.000	13.278	44	-53	349	1.10	4.0	6.7	-67.573 18.231
30	-67.722	18.233	18.000	13.278	60	-139	47	1.10	4.0	6.7	-67.597 18.343
31	-67.568	17.811	18.000	13.278	64	-48	310	1.10	4.0	6.7	-67.698 17.915
32	-65.797	17.839	18.000	13.278	74	-5	335	1.10	4.0	6.7	-65.869 17.986
33	-67.961	17.713	18.000	13.278	6	80	334	1.10	4.0	6.7	-68.036 17.859
34	-67.779	18.008	18.000	13.278	21	97	307	1.10	4.0	6.7	-67.915 18.105
35	-67.975	18.148	18.000	13.278	41	38	41	1.10	4.0	6.7	-67.863 18.270
36	-65.853	17.727	18.000	13.278	34	100	320	1.10	4.0	6.7	-65.962 17.851

36 events

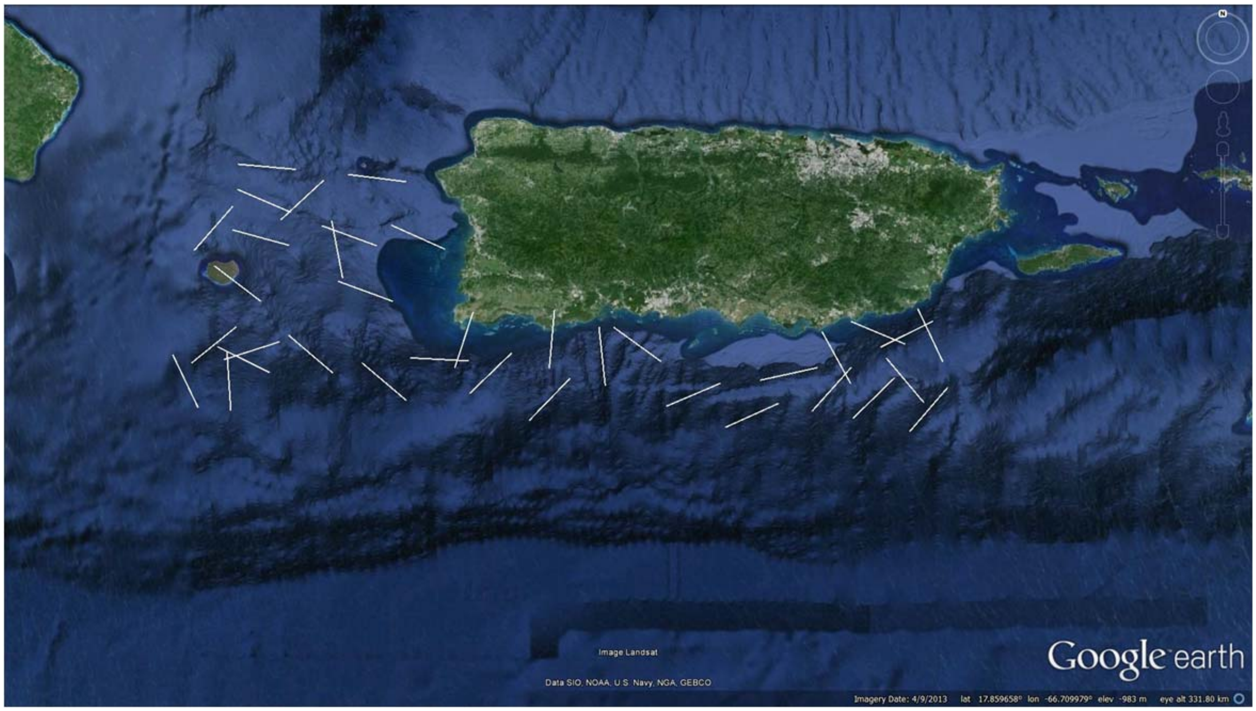

Figure 3 - Sources for tsunami scenarios for Puerto Rico West to Southeast.

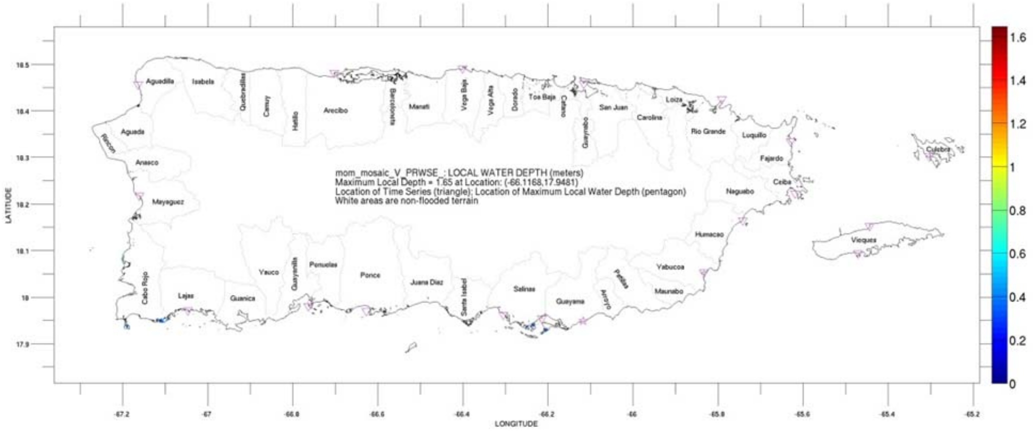

Figure 4 – Puerto Rico West to Southeast's MOM.

Up to now we have presented results for the faults that were originally supplied by Dr. Victor Huerfano, and used in the 2000-2013 FEMA-sponsored project. These consist of 312 scenarios.

MAXIMUM OF THE MOM'S FOR VICTOR HUERFANO'S ORIGINAL 312 FAULTS

We now put together all of the above MOM's and determine the Maximum of the MOM's for Victor Huerfano original faults. The result is shown in Figure 34.

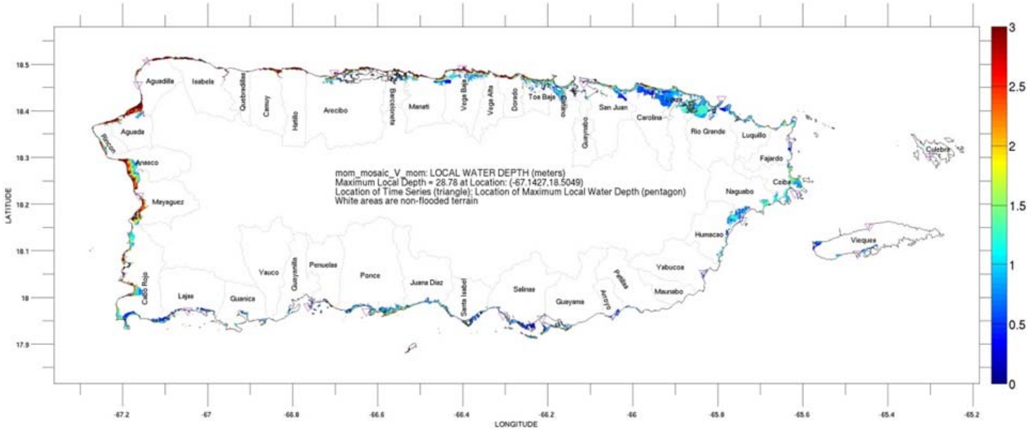

Figure 5 – MOM of MOM of 19° N, Anegada, Eastern Dominican Republic, Leeward Islands, McCann, Septentrional, Sombrero, Mona Channel, Muertos Trough, North Platform, Puerto Rico Trench, Puerto Rico West to Southeast. A total of 312 scenarios.

LOCAL SCENARIOS BASED ON EIGHT ADDITIONAL SCENARIOS FROM VICTOR HUERFANO (not included in the 2003 results)

Later on, Dr. Huerfano supplied eight additional potential sources based on local historical earthquakes. The locations of these sources are shown in Figure 35.

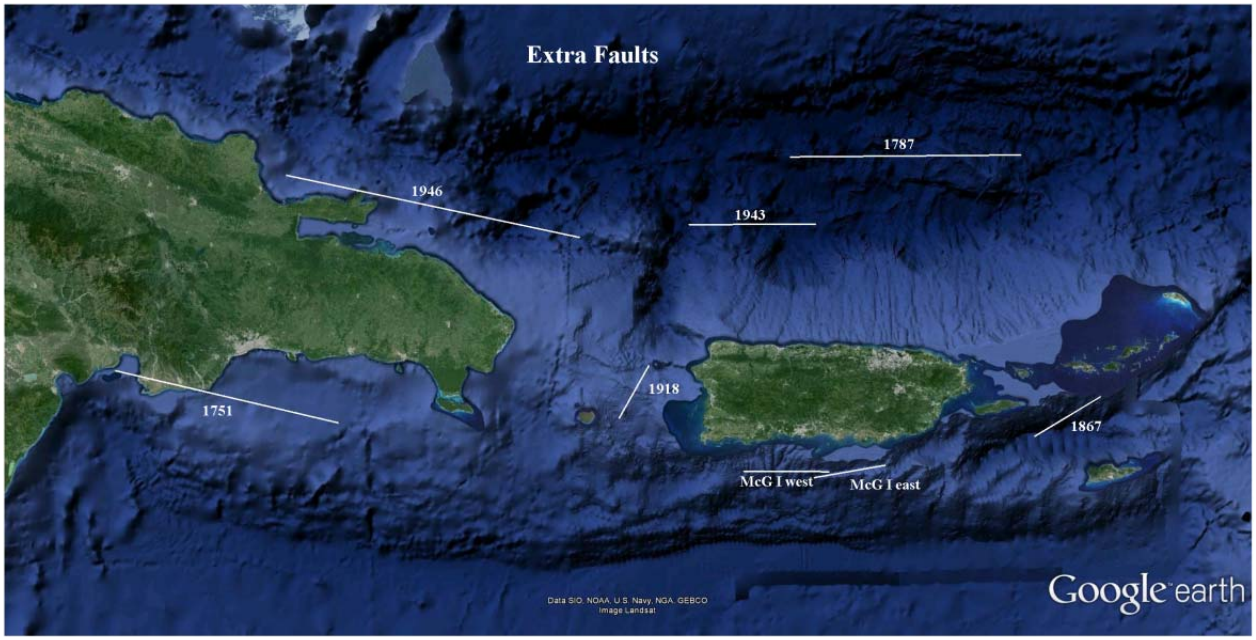

Figure 6 – Extra faults supplied by V. Huerfano. Eight scenarios.

Fault: TFCMM and McG Inv 1 and McG Inv 2: (NOTE: the fault's location for these faults is given in the MOST convention, where what is given is the coordinate of the middle of the lower border of the deformation plane. These are the coordinates supplied to MOST, using the switch 0 in the input file for generation/propagation. What is drawn in the figure above is the upper border of the deformation plane.) What is called Fault TFCMM consists of six scenarios as given in the table below (events that were recorded in the past), plus two additional ones named McG Inv 1 and McG Inv 2.

Scenario (Year)	Longitude (°)	Latitude (°)	Length (km)	Width (km)	Dip (°)	Rake (°)	Strike (°)	Slip (m)	Depth (km)	Mw
1751	-69.93	18.82	250	75	11	90	282	3.5	4	8.3
1787	-66.00	18.94	150	75	25	90	90	3.5	4	8.1
1867	-64.98	17.97	50	20	67	-106	60	3	4	7.4
1918	-67.67	18.30	36	20	54	-127	207	3	4	7.3
1943	-66.95	18.82	80	40	19	60	90	2	4	7.6
1946	-69.03	18.53	195	95	22	76	102	3.75	4	8.3
McG Inv 1 East	-66.115	17.8033	46	20	10	90	261	1.8	4	7.2
McG Inv 2 west	-66.4517	17.7708	53	20	10	90	271	1.7	4	7.2

8 events

The following table shows the starting and ending locations of the fault traces shown in Figure 35 above.

	1751	1787	1867	1918	1943	1946	McG Inv1	McG Inv1
Start	-69.37 18.05;	-66.67 19.55;	-65.22 17.95;	-67.52 18.38;	-67.28 19.17;	-69.7 19.45	-66.1150 17.8033;	-66.4517 17.7708;
End	-70.73 18.33	-65.27 19.55	-64.81 18.17	-67.7 18.08	-66.5183 19.17	-67.93 19.1	-66.5440 17.7381	-66.9621 17.7785

The following figures (36 to 41) show the inundation for each of the above TFCMM faults, and the two ones called “McG Inv 1 east” and “McG Inv 2 west”.

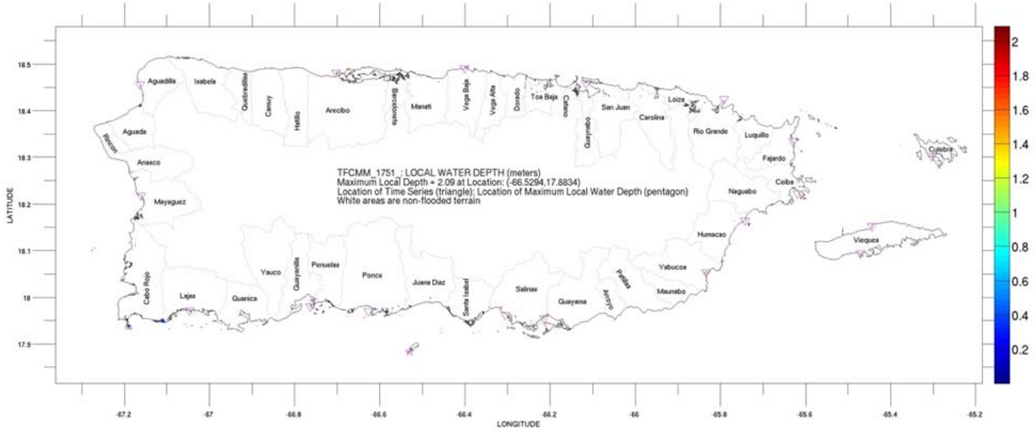

Figure 7 – MEOW for 1751 scenario.

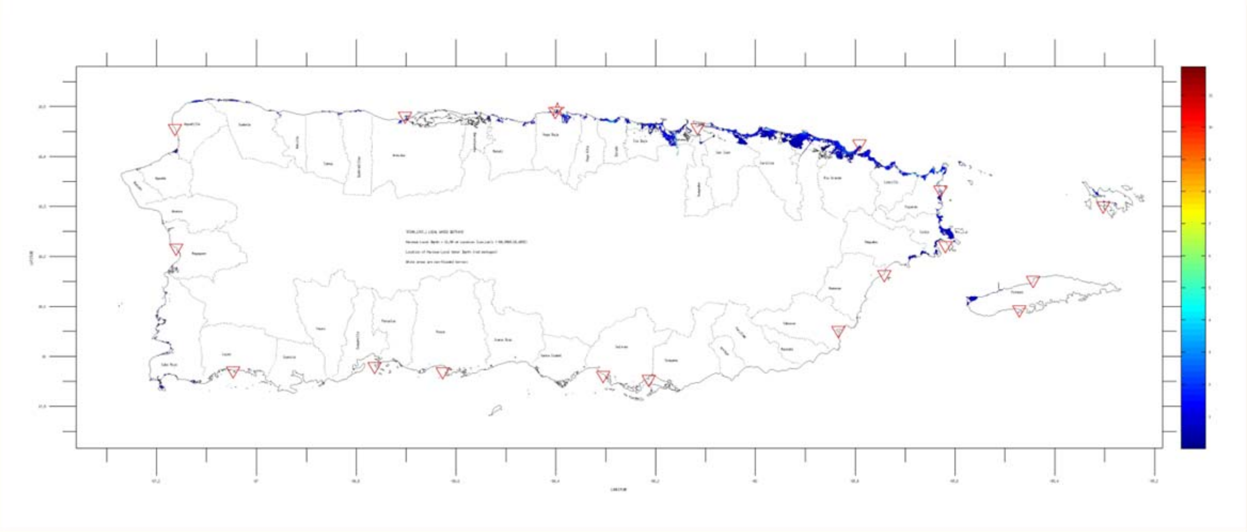

Figure 8 – MEOW for 1787 scenario.

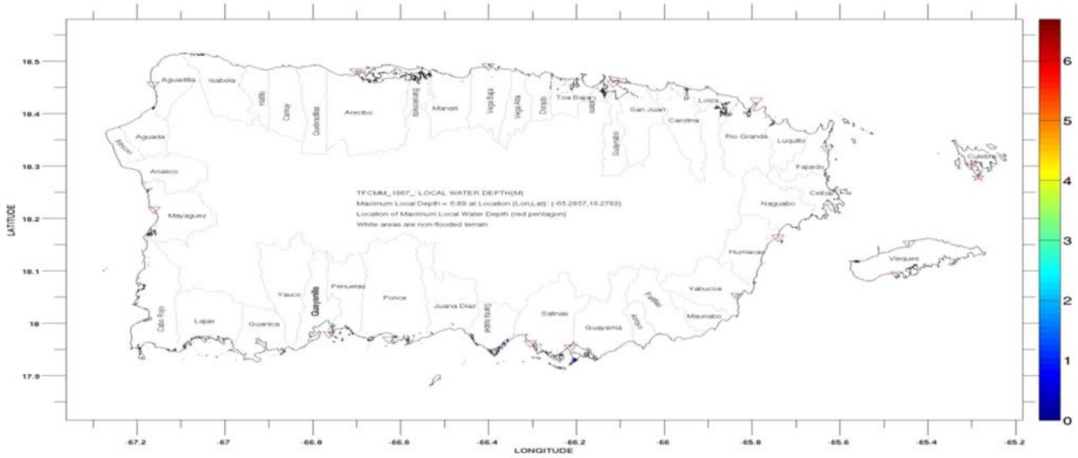

Figure 9 – MEOW for 1867 scenario.

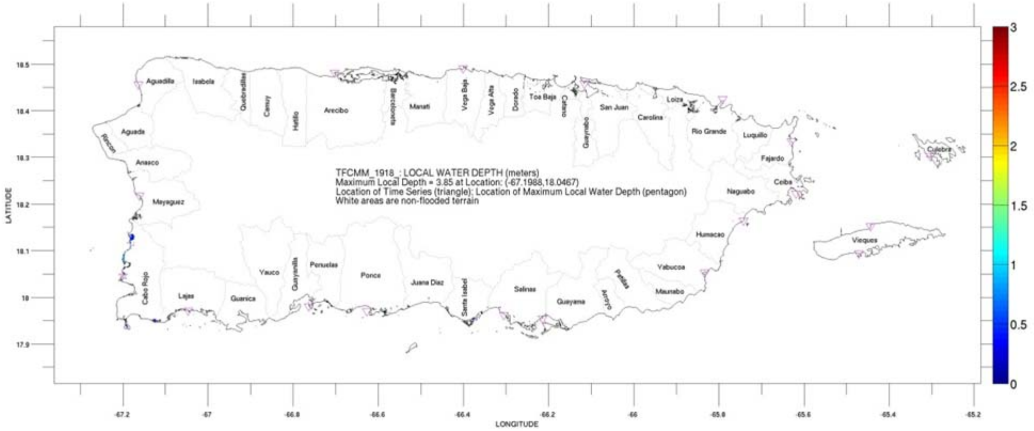

Figure 39 - MEOW for 1918 scenario.

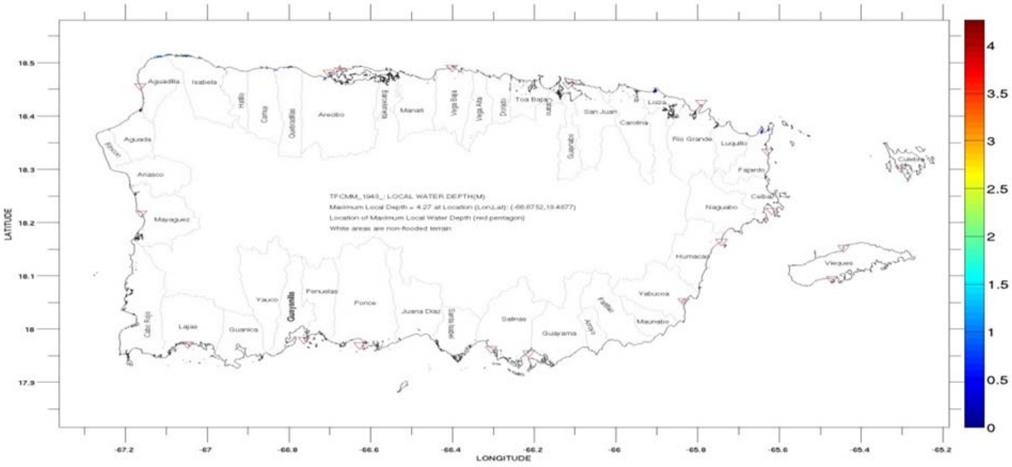

Figure 40 – MEOW for 1943 scenario.

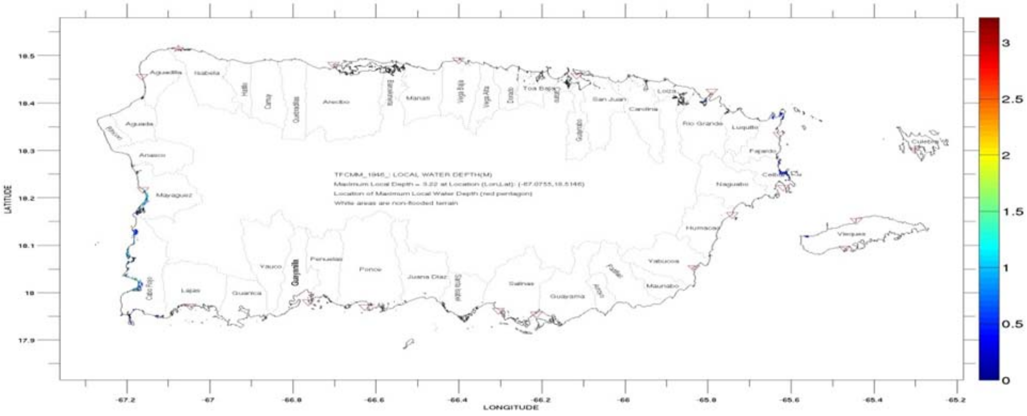

Figure 41 – MEOW for 1946 scenario.

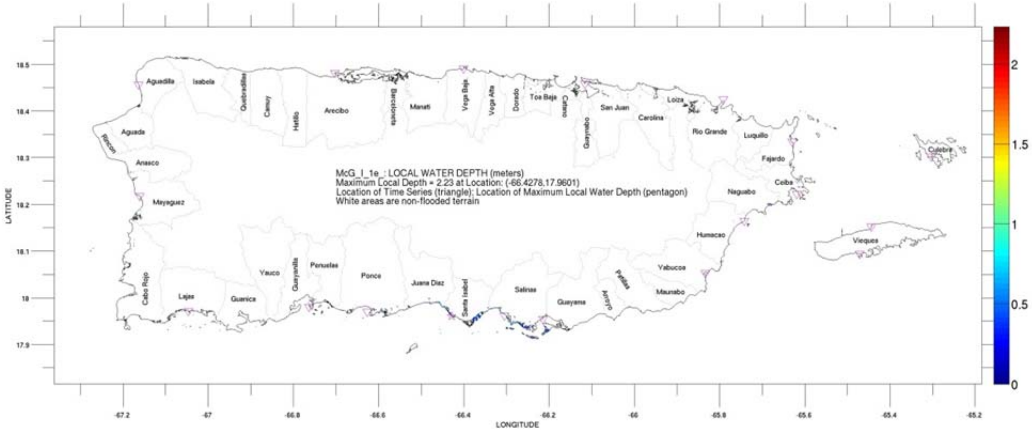

Figure 42 – MEOW for McG Inv 1 east scenario.

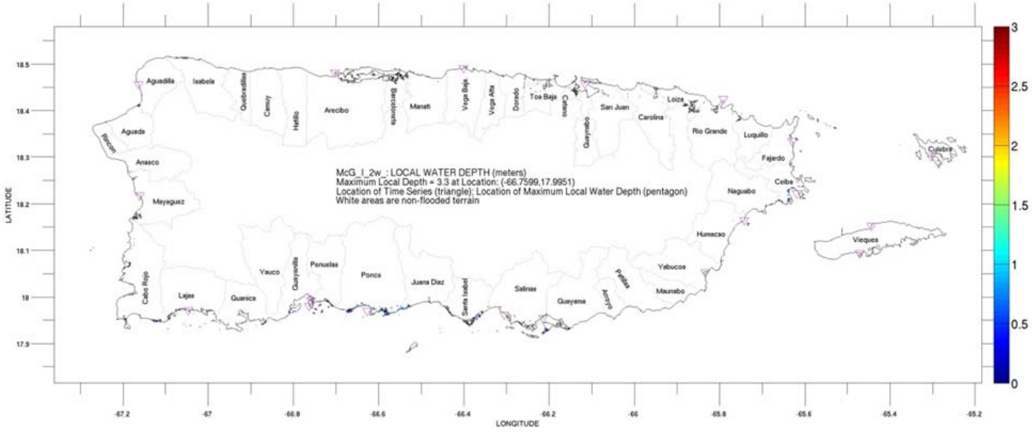

Figure 43 - MEOW for McG Inv 2 west scenario.

MAXIMUM OF THE MOM'S FOR THE COMBINATION OF VICTOR HUERFANO'S ORIGINAL FAULTS WITH THE EIGHT HISTORICAL FAULTS (TFCMM AND McG Inv 1 & 2)

Figure 44 shows the MOM in which the 312 original faults were combined with the 8 additional ones.

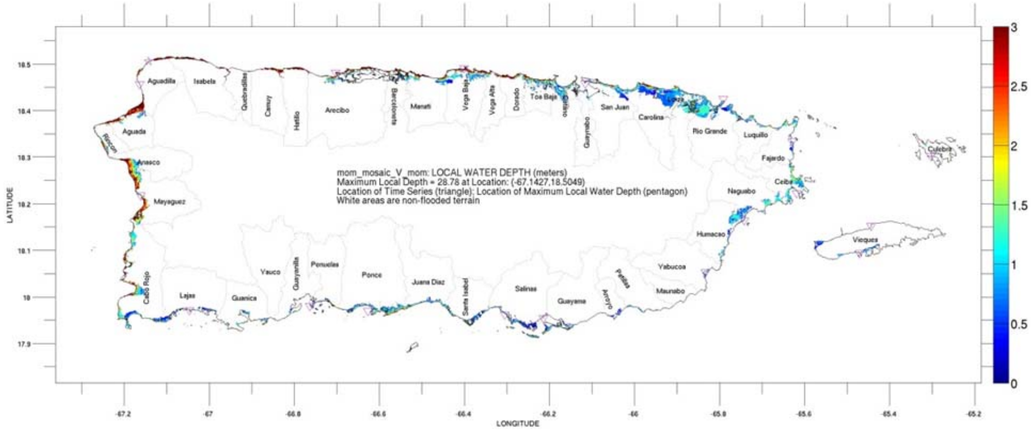

Figure 10 – Local faults MOM of MOM, including extra faults (McG_I_1e, McG_I_2w, TFCMM_1751, TFCMM_1787, TFCMM_1867, TFCMM_1918, TFCMM_1943, TFCMM_1946). 320 scenarios.

FEDERAL EMERGENCY MANAGEMENT AGENCY CATASTROPHIC SCENARIO

After all of the above computer runs were made, the Federal Emergency Management Agency, in combination with the USGS, the Puerto Rico Seismic Network, Argonne National Laboratory, and Los Alamos National Laboratory, decided to add another local scenario, called the FEMA Catastrophic Scenario. The fault parameters for the four segments as supplied are given below.

Fault: FEMA (NOTE: The fault's origin is given following the MOST convention, that is, the coordinates of the middle of the lower border of the fault plane. The switch in the input file was set to 0).

Segment	Longitude (°)	Latitude (°)	Length (km)	Width (km)	Dip (°)	Rake (°)	Strike (°)	Slip (m)	Depth (km)	Mw	End point (°)
1	-64.80	19.0	66.92	72.59	45	90	109	5.473	10	8.0	-65.40 19.0
2	-65.40	19.0	63.08	72.59	45	75	90	5.473	10	8.0	-66.50 19.25
3	-66.50	19.25	118.90	72.59	45	85	103	5.473	10	8.2	-67.00 19.25
4	-67.00	19.25	52.49	72.59	45	75	90	5.473	10	7.9	-66.5 19.25

The overall Mw, using the sum of the lengths (since the widths and slips for the four segments are the same) is Mw 8.4.

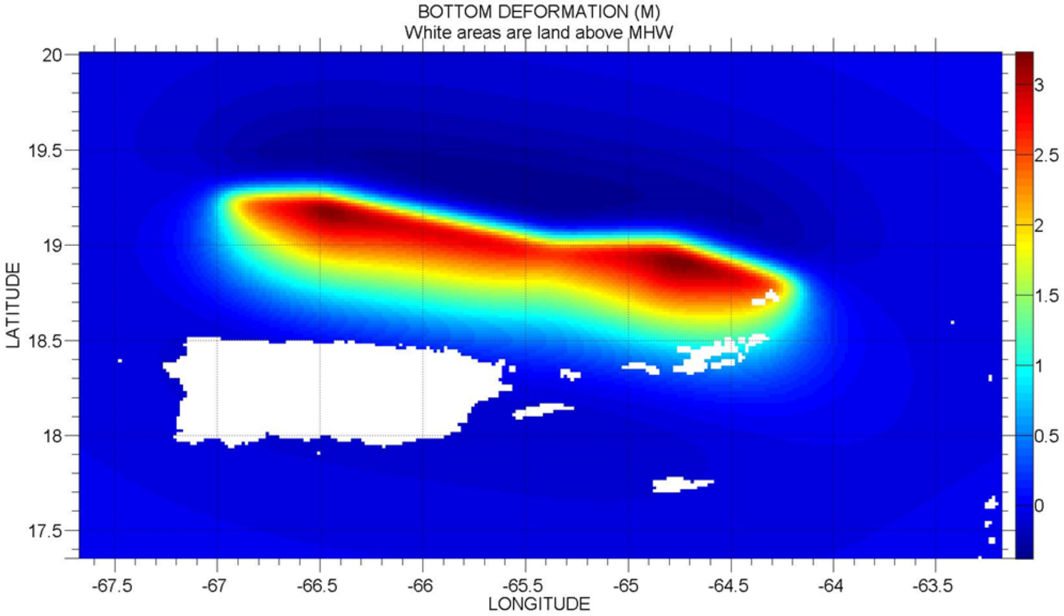

Figure 11 – Deformation for FEMA's scenario (Mw 8.4).

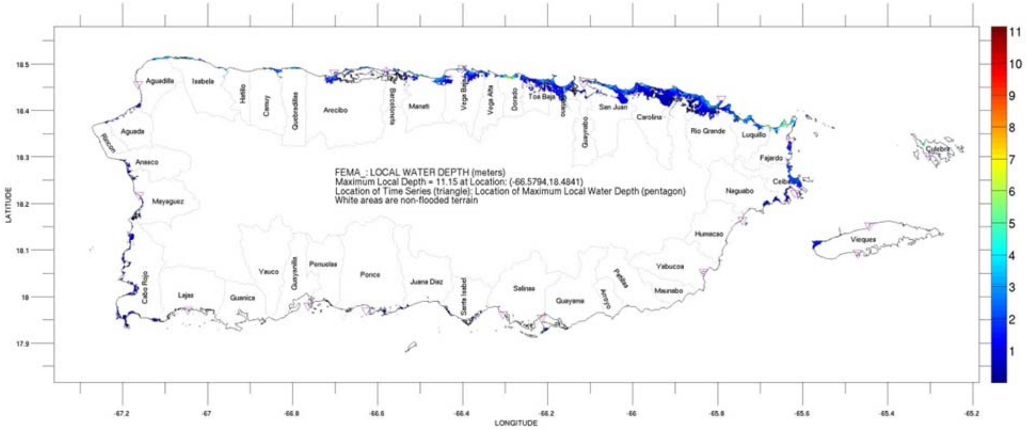

Figure 12 – MEOW for FEMA's scenario (Mw 8.4).

MAXIMUM OF THE MOM'S FOR THE COMBINATION OF VICTOR HUERFANO'S ORIGINAL FAULTS WITH THE EIGHT HISTORICAL FAULTS (TFCMM AND McG Inv 1 & 2), AND WITH THE FEMA SCENARIO

The following figure shows the MOM including all of the above scenarios (321), which are considered local.

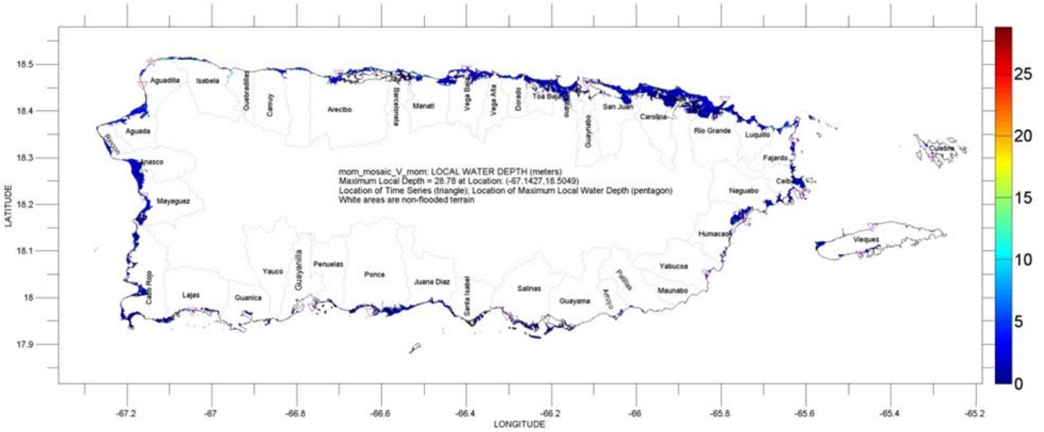

Figure 13 – Combination of FEMA's MEOW with local faults MOM of MOM, including extra faults (McG_I_1e, McG_I_2w, TFCMM_1751, TFCMM_1787, TFCMM_1867, TFCMM_1918, TFCMM_1943, TFCMM_1946). That is, Figure 25 with Figure 24. This is the MOM of MOM for all tsunamis considered as local. This is the final inundation map using 321 scenarios (312+9).

The above figure (Figure 47) shows the composite of the inundated areas for all 321 scenarios considered up to now.

ACKNOWLEDGMENTS

I would like to acknowledge the support and help of Mr. Harry Justiniano, the undergraduate student, Mr. Giovanni Seijo, and especially of the graduate student, Mr. Jose Benitez. Finally, the support of the USA National Tsunami Hazard Mitigation Program, of the original PI of the project, Ms. Christa von Hillebrandt, and of Dr. Victor Huerfano, of the Puerto Rico Seismic Network, is greatly appreciated.

APPENDIX 1
Manning's n for Channels (Chow, 1959).

Type of Channel and Description	Minimum	Normal	Maximum
Natural streams - minor streams (top width at floodstage < 100 ft)			
1. Main Channels			
a. clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. same as above, but more stones and weeds	0.030	0.035	0.040
c. clean, winding, some pools and shoals	0.033	0.040	0.045
d. same as above, but some weeds and stones	0.035	0.045	0.050
e. same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
f. same as "d" with more stones	0.045	0.050	0.060
g. sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
2. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
a. bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050
b. bottom: cobbles with large boulders	0.040	0.050	0.070
3. Floodplains			
a. Pasture, no brush			
1.short grass	0.025	0.030	0.035
2. high grass	0.030	0.035	0.050
b. Cultivated areas			
1. no crop	0.020	0.030	0.040
2. mature row crops	0.025	0.035	0.045
3. mature field crops	0.030	0.040	0.050
c. Brush			
1. scattered brush, heavy weeds	0.035	0.050	0.070
2. light brush and trees, in winter	0.035	0.050	0.060
3. light brush and trees, in summer	0.040	0.060	0.080
4. medium to dense brush, in winter	0.045	0.070	0.110
5. medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. dense willows, summer, straight	0.110	0.150	0.200
2. cleared land with tree stumps, no sprouts	0.030	0.040	0.050
3. same as above, but with heavy growth of	0.050	0.060	0.080

sprouts			
4. heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
5. same as 4. with flood stage reaching branches	0.100	0.120	0.160
4. Excavated or Dredged Channels			
a. Earth, straight, and uniform			
1. clean, recently completed	0.016	0.018	0.020
2. clean, after weathering	0.018	0.022	0.025
3. gravel, uniform section, clean	0.022	0.025	0.030
4. with short grass, few weeds	0.022	0.027	0.033
b. Earth winding and sluggish			
1. no vegetation	0.023	0.025	0.030
2. grass, some weeds	0.025	0.030	0.033
3. dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
4. earth bottom and rubble sides	0.028	0.030	0.035
5. stony bottom and weedy banks	0.025	0.035	0.040
6. cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-excavated or dredged			
1. no vegetation	0.025	0.028	0.033
2. light brush on banks	0.035	0.050	0.060
d. Rock cuts			
1. smooth and uniform	0.025	0.035	0.040
2. jagged and irregular	0.035	0.040	0.050
e. Channels not maintained, weeds and brush uncut			
1. dense weeds, high as flow depth	0.050	0.080	0.120
2. clean bottom, brush on sides	0.040	0.050	0.080
3. same as above, highest stage of flow	0.045	0.070	0.110
4. dense brush, high stage	0.080	0.100	0.140
5. Lined or Constructed Channels			
a. Cement			
1. neat surface	0.010	0.011	0.013
2. mortar	0.011	0.013	0.015
b. Wood			
1. planed, untreated	0.010	0.012	0.014
2. planed, creosoted	0.011	0.012	0.015
3. unplaned	0.011	0.013	0.015
4. plank with battens	0.012	0.015	0.018

5. lined with roofing paper	0.010	0.014	0.017
c. Concrete			
1. trowel finish	0.011	0.013	0.015
2. float finish	0.013	0.015	0.016
3. finished, with gravel on bottom	0.015	0.017	0.020
4. unfinished	0.014	0.017	0.020
5. gunite, good section	0.016	0.019	0.023
6. gunite, wavy section	0.018	0.022	0.025
7. on good excavated rock	0.017	0.020	
8. on irregular excavated rock	0.022	0.027	
d. Concrete bottom float finish with sides of:			
1. dressed stone in mortar	0.015	0.017	0.020
2. random stone in mortar	0.017	0.020	0.024
3. cement rubble masonry, plastered	0.016	0.020	0.024
4. cement rubble masonry	0.020	0.025	0.030
5. dry rubble or riprap	0.020	0.030	0.035
e. Gravel bottom with sides of:			
1. formed concrete	0.017	0.020	0.025
2. random stone mortar	0.020	0.023	0.026
3. dry rubble or riprap	0.023	0.033	0.036
f. Brick			
1. glazed	0.011	0.013	0.015
2. in cement mortar	0.012	0.015	0.018
g. Masonry			
1. cemented rubble	0.017	0.025	0.030
2. dry rubble	0.023	0.032	0.035
h. Dressed ashlar/stone paving	0.013	0.015	0.017
i. Asphalt			
1. smooth	0.013	0.013	
2. rough	0.016	0.016	
j. Vegetal lining	0.030		0.500