DEVELOPMENT OF THE STAND BY INUNDATION MODEL FOR PONCE, PUERTO RICO

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Contents

Abstract 7
1.0 Background and Objectives 7
2.2.1 Data Assimilation and Inversion 9
2.2.2. Standby Inundation Model Forecasting 10
3.0 SIM Setup for Ponce, Puerto Rico 11
3.1 Study Area 11
3.2 Bathymetry and Topography 11
3.3 Tide gauges 13
3.4 Reference Grids 13
3.4 Optimized Grids 18
4.0 Results 25
5.0 Conclusions 39
6.0 Acknowledgements 39
7.0 References 39
Appendix 1 41
Ponce Reference Grids *.in file 41
Ponce Reference Grids *.lis file 42
Ponce Optimized Grids *.in file 43
Ponce Optimized *.lis file 44

DRAFT

List of Tables

Table 1 Sources used for testing the Ponce, Puerto Rico SIM. 10

Table 2 Summary of Reference grids for Ponce, Puerto Rico. 14

Table 3 Grids used during optimization attempts for Ponce. 19

Table 4 MOST set up of reference and optimized models for Ponce, Puerto Rico. 38

DRAFT

List of Figures

Figure 1 Caribbean Sea and the island of Puerto Rico. Also shown is the approximate location of the Ponce metropolitan area. 8

Figure 2 - Location of unit sources for the Caribbean Sea region. Sources A and B: 86-92 (Muertos Trough), A and B: 37-49 (Lesser Antilles Trench), and A and B: 21-29 (South Caribbean Marginal Fault) were used in this study. 10

Figure 3 Depth contour plot of 3 arc sec grid supplied by NGDC. Note varying shelf width. 12

Figure 4 Depth contour plot of the high resolution (1/3 sec) grid supplied by NGDC for the Ponce metropolitan area. Note numerous islands and varying shelf width... 12

Figure 5 Depth contour plot of the common reference grid A (12 arc sec) to be used for Ponce. Reference grids B and C are superimposed in white. 15

Figure 6 Depth contour plot of reference grid B, Ponce. Reference grid C is superimposed in white. 16

Figure7 Depth contour plot of reference grid C, Ponce. White cross denotes warning point location. Note complex bathymetry and local shoaling at warning point. 17

Figure 8 Google Earth view of Ponce, Puerto Rico C grid (approximate). 18

Figure 9 Depth contour plot of Puerto Rico 12 arc second reference grid A with extent of cropped Puerto Rico 18 arc second optimized grid A superimposed in white. Light blue line denotes 0 m elevation. 20

Figure 10 Depth contour plot of cropped Puerto Rico18 arc second optimized grid A with extent of cropped Ponce 6 arc second optimized grid B superimposed in white and extent of cropped Ponce 1 arc second optimized grid C superimposed in blue. . 21

Figure 11 Depth contour plot of Ponce 6 arc second reference grid B with extent of cropped Ponce 6 arc second optimized grid B superimposed in white. 22

Figure 12 Depth contour plot of Ponce 1 arc second reference grid C with extent of cropped Ponce 1 arc second optimized grid C superimposed in blue. White cross

DRAFT

denotes warning point location. Note complex bathymetry and local shoaling at warning point. 23

Figure 13 Depth contour plot of cropped Ponce 6 arc second optimized grid B with extent of cropped Ponce 1 arc second optimized grid C superimposed in white. 24

Figure 14 Depth contour plot of cropped Ponce 1 arc second optimized grid C. Note complex bathymetry. 25

Figure 15 Time series at warning point, Ponce, for Muertos Trough source. Red line is for reference grids. Blue line is for optimized grids. Top: Comparison, first 4 hours of simulation. Bottom: 10 hours of simulation, reference only. 26

Figure 16 Time series at warning point, Ponce, for Lesser Antilles Trench source. Red line is for reference grids. Blue line is for optimized grids. Top: Comparison, first 4 hours of simulation. Bottom: 10 hours of simulation, reference only 27

Figure 17 Time series at warning point, Ponce, for South Caribbean Marginal Fault source. Red line is for reference grids. Blue line is for optimized grids. Top: Comparison, first 4 hours of simulation. Bottom: 10 hours of simulation, reference only. 28

Figure 18 Maximum sea surface elevation for Ponce optimized grid C (top) vs. reference grid C (bottom), Muertos Trough sources. Simulation time for optimized grid, 4 hours; reference grid, 10 hours. Thick black line indicates 0 m elevation prior to co-seismic deformation. Thin blue line indicates vertical extent of co-seismic deformation (-1.42 m). Black cross denotes location of warning point. 29

Figure 19 Maximum sea surface elevation for Ponce optimized grid C (top) vs. reference grid C (bottom), Lesser Antilles Trench sources. Simulation time for optimized grid, 4 hours; reference grid, 10 hours. Thick black line indicates 0 m elevation. No co-seismic deformation was observed in these simulations. Black cross denotes location of warning point. 30

Figure 20 Maximum sea surface elevation for Ponce optimized grid C (top) vs. reference grid C (bottom), Southern Caribbean Marginal Fault sources. Simulation time for optimized grid, 4 hours; reference grid, 10 hours. Thick black line indicates 0 m elevation. No co-seismic deformation was observed in these simulations. Black cross denotes location of warning point. 31

Figure 21 Maximum sea surface elevation for optimized grid B (top) vs. reference grid B (bottom), Muertos Trough sources. Simulation time for reference grid was 10 hours; optimized grid, 4 hours. Extent of optimized cropped grid C outlined in white. Thin white line indicates 0 m elevation prior to co-seismic deformation. Black cross denotes location of warning point. 32

DRAFT

Figure 22 Maximum sea surface elevation for optimized grid B (top) vs. reference grid B (bottom), Lesser Antilles Trench sources. Simulation time for reference grid was 10 hours; optimized grid, 4 hours. Extent of optimized cropped grid C outlined in white. Thin white line indicates 0 m elevation. Black cross denotes location of warning point. 33

Figure 23 Maximum sea surface elevation for optimized grid B (top) vs. reference grid B (bottom), Southern Caribbean Marginal Fault sources. Simulation time for reference grid was 10 hours; optimized grid, 4 hours. Extent of optimized cropped grid C outlined in white. Thin white line indicates 0 m elevation. Black cross denotes location of warning point. 34

Figure 24 Maximum sea surface elevation for optimized grid A (top) vs. reference grid A (bottom), Muertos Trough sources. Simulation time for reference grid was 10 hours; optimized grid, 4 hours. Black cross denotes location of warning point. 35

Figure 25 Maximum sea surface elevation for optimized grid A (top) vs. reference grid A (bottom), Lesser Antilles Trench sources. Simulation time for reference grid was 10 hours; optimized grid, 4 hours. Black cross denotes location of warning point. 36

Figure 26 Maximum sea surface elevation for optimized grid A (top) vs. reference grid A (bottom), Southern Caribbean Marginal Fault sources. Simulation time for reference grid was 10 hours; optimized grid, 4 hours. Black cross denotes location of warning point. 37

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Development of a Standby Inundation Model for Ponce, Puerto Rico

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Abstract

This report describes the development of Standby Inundation Models (SIMs) for Ponce, Puerto Rico, as a component of the NOAA SIFT system. The optimized MOST model can obtain accurate amplitude of first waves and reasonable inundation limit within 10 minutes for the study area upon receiving the information of the earthquake source determined from real-time data assimilation and inversion. The model is validated using numerical results from a high-resolution MOST reference model since there are no historical tsunami instrumental records for the island. The developed SIM's are tested against different scenarios of large virtual tsunamis numerically generated from the Muertos Trough, the Lesser Antilles Trench, and the South Caribbean Marginal Fault subduction zones.

1.0 Background and Objectives

The NOAA Center for Tsunami Research (NCTR) at NOAA Pacific Marine Environmental Laboratory (PMEL) is developing a tsunami forecasting tool known as Short-term Inundation Forecasting for Tsunamis (SIFT) for NOAA Tsunami Warning Centers (Titov *et al.*, 2005). The primary goal of the system is to provide NOAA Tsunami Warning Centers with operational tools that combine real-time deep-ocean Bottom Pressure Recorder (BPR) recordings from the DART tsunameter network (González *et al.*, 2005) and seismic data with a suite of numerical codes, Method of Splitting Tsunami (MOST) (Titov and Synolakis, 1998; Titov and González, 1997), to produce efficient forecasts of tsunami arrival time, heights and inundation. To achieve accurate and detailed information on the likely impact of incoming tsunami on specific coastal communities within certain time limits and to reduce false alarms, Standby Inundation Models (SIMs) are being developed and integrated as crucial components of SIFT for a limited number of 75 US coastal cities and territories that are potentially at most risk.

The primary objective of the present study is to develop and test SIMs for real-time forecast of tsunami waves and inundation at the city of Ponce on the island of Puerto Rico. Figure 1 shows the Caribbean Sea and the island of Puerto Rico. Also shown is the approximate location of the city of Ponce (south coast), the location of the SIMs.

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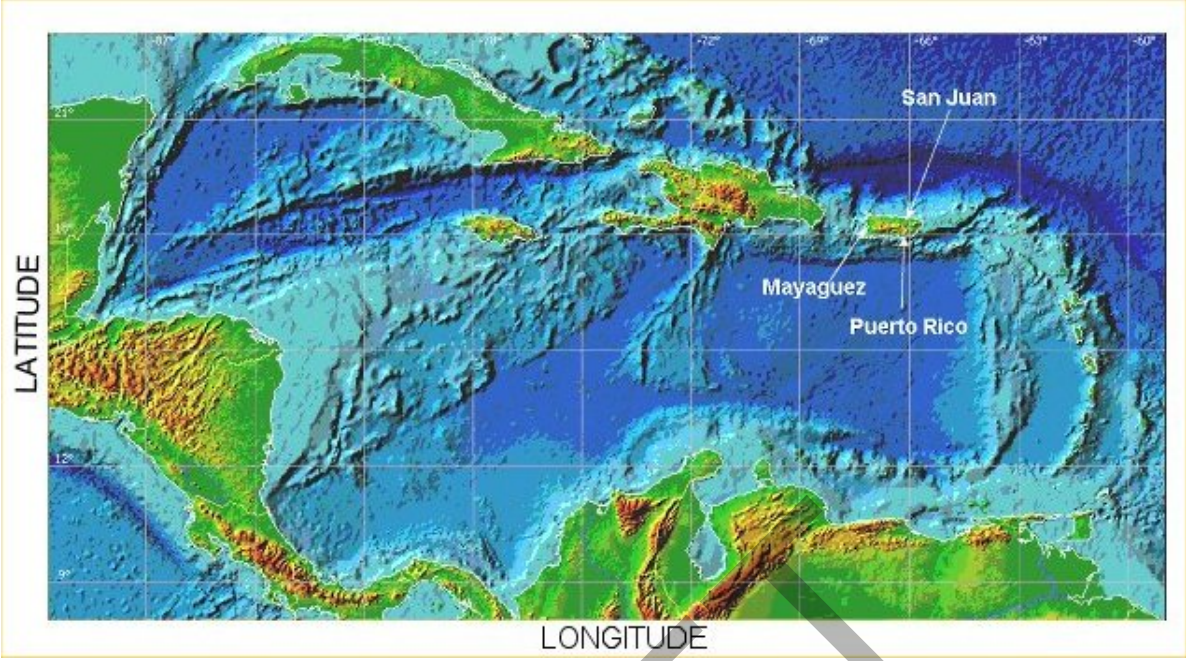

Figure 1 Caribbean Sea and the island of Puerto Rico. Also shown is the approximate location of the Ponce metropolitan area.

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2.1 Tsunami Model

MOST (Titov and Synolakis, 1998; Titov and González, 1997) is a 2D finite-differences numerical model based on the nonlinear long-wave approximation. It uses a splitting scheme to separate the original two-dimensional problem into two sequential one-dimensional problems.

The MOST model accommodates a base level grid (0), for wave transoceanic propagation and three levels of telescoping grids (A, B, and C) with increasing spatial and temporal resolution for simulation of wave inundation onto dry land. The linear solution is evaluated at the base level while the nonlinear are calculated at the next three. Grid 0 is not dynamically couple with the other three, which is more efficient since it can provide multiple sets of boundary conditions for subsequent detailed calculations at different locations.

The numerical solution is obtained by an explicit finite-differences scheme with a second-order approximation in space and first order in time. The MOST model uses a Neumann-type technique to determine the waterline position through the computed flow velocity.

2.2 Methodology for NOAA SIFT System

The PMEL real-time tsunami forecasting scheme is a process that comprises of two steps, (1) data assimilation and inversion, and (2) forecasting by Standby Inundation Models (SIMs). Each one of these two steps is explained next

2.2.1 Data Assimilation and Inversion

Besides seismic and coastal tide gauges, real-time deep ocean bottom pressure data from the National Tsunami Hazard Mitigation Program (NTHMP) tsunameter network, Deep-ocean Assessment and Reporting of Tsunamis (DART), is used as a primary data source since it can provide rapid tsunami observation without harbor and instrument responses. The linearity of wave dynamics of tsunami propagation in the deep ocean allows for applications of inversion schemes to construct a tsunami scenario based on the best fit to given tsunameter data. Details of the inversion method can be found in Titov *et al*. (2003) and Wei *et al*. (2003).

PMEL has developed a linear propagation model database for unit sources in the Atlantic and Caribbean Sea, with each unit source a typical Mw = 7.5 subduction zone earthquake. Based on a sensitivity study of far-field tsunami characteristics (Titov *et al*., 1999), the parameters of the unit sources are: length = 100 km, width = 50 km, dip = 15°, rake = 90°, depth = 5 km, slip = 1 m. The strike of each source is aligned with the local orientation of the subduction zone. The model simulation results for each unit solution, including amplitudes and velocities, are stored in a database. The database also provides the offshore forecast of tsunami amplitudes and all other wave parameters around the Caribbean Sea and North Atlantic Ocean immediately once the data assimilation is complete (Gica et al. 2008). The inversion algorithm, which combines real-time tsunami-meter data of offshore amplitude with the propagation database, provides an accurate offshore tsunami scenario without additional time-consuming model runs.

The locations of the unit sources for the Caribbean region are shown in Fig. 2. Table 1 presents the combination of unit sources from the forecast model database used for the optimization process in this report. At each subduction zone, two lines of sources (A – top; B – bottom) are placed next to each other. The unit sources corresponding to segments A and B: 86-92 (Mw = 9.0, along the Muertos Trough), A and B: 37-49 (Mw = 9.0, Lesser Antilles Trench) and A and B: 21 - 29 (Mw = 9.0, South Caribbean Marginal Fault) were used. These correspond to extreme earthquakes with maximum estimated magnitudes possible for these seismic zones.

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Source Location	Unit Sources	Slip for each unit source (m)	Mw
Muertos Trough	86 through 92 Rows A and B	11	9.0
Lesser Antilles Trench	37 through 49 Rows A and B	11	9.0
South Caribbean Marginal Fault	21 through 29 Rows A and B	11	9.0

Table 1 Sources used for testing the Ponce, Puerto Rico SIM.

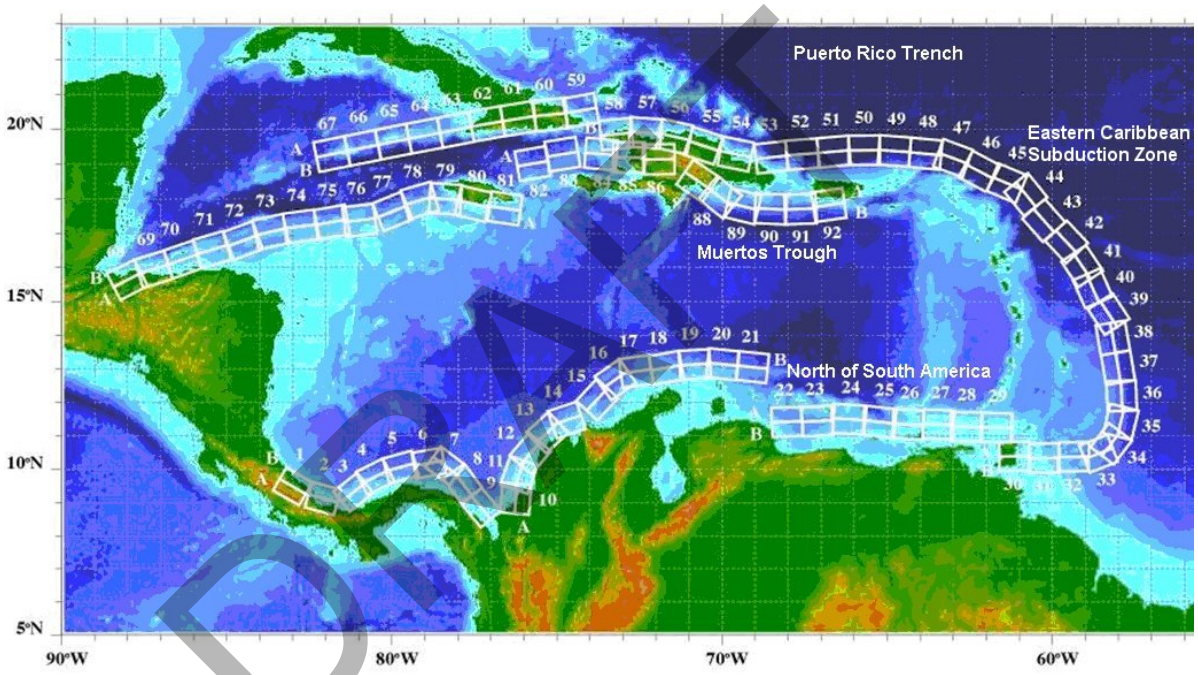

Figure 2 - Location of unit sources for the Caribbean Sea region. Sources A and B: 86-92 (Muertos Trough), A and B: 37-49 (Lesser Antilles Trench), and A and B: 21-29 (South Caribbean Marginal Fault) were used in this study.

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2.2.2. Standby Inundation Model Forecasting

A SIM applies the non-linear components of the MOST model using three nested grids (A, B, and C), with increasing resolution to telescope into the inundation forecasting area. The inundation area (grid C) includes the high concentration of population in the coastal communities, and the National Weather Service so-called Warning Points (WP).

To provide site-specific forecasting for rapid, critical decision-making in emergency management, SIMs are implemented and optimized for both speed and accuracy. First,

a SIM utilizes the pre-computed time series of offshore wave height and depth-averaged velocity from the database as the boundary and initial conditions once the offshore scenario is defined. Second, by reducing the calculation areas and grid resolutions, the optimized setup can provide forecasting results within 10 minutes (for a minimum of 4 hours of simulation time), which allows larger time steps without violations of the CFL conditions. Finally, to insure forecasting accuracy, results from the optimized runs are validated with historical tsunami tide gauge records (if available) as well as a reference model run made with higher resolutions and larger calculation domains.

3.0 SIM Setup for Ponce, Puerto Rico

3.1 Study Area

SIMs are being prepared for Ponce, Puerto Rico. The Ponce area is exposed to events propagating in from the south, east, and west. While there is no historical evidence of any significant tsunami impacting the Ponce area, the growth of population in the coastal areas potentially exposed to tsunamis has been very large. Ponce beaches are filled with tourists year-round.

The bathymetry offshore of Ponce is relatively complicated. To the south, deep waters are found close to shore, but there exist a number of small islands, with very irregular bathymetry due to the presence of reefs and shoals. This complicates the task of obtaining an optimized grid for Ponce.

3.2 Bathymetry and Topography

For this study the National Geophysical Data Center (NGDC) provided high-resolution gridded data based on recent shallow water LIDAR topographic and bathymetric surveys and multi-beam surveys for deeper waters. A 1 arc second grid was supplied that covered the entire island, as shown in Figure 3. Its parameters are given in Table 2. A detailed report accompanied the NGDC data (Taylor *et al.*, 2007), and should be consulted for details regarding data processing.

NGDC additionally supplied a higher resolution grid for the Ponce metropolitan area. Figure 4 show the Ponce metropolitan area. As can be seen in Figures 1,3-4, Puerto Rico generally has a very narrow shelf marked by a very sharp transition from shelf to deep waters, with bottom slopes > 45° in many locations. Where the shelf is relatively wide, it contains complex, rapidly varying, bathymetric features. These conditions will test the capabilities of any nonlinear shallow water model.

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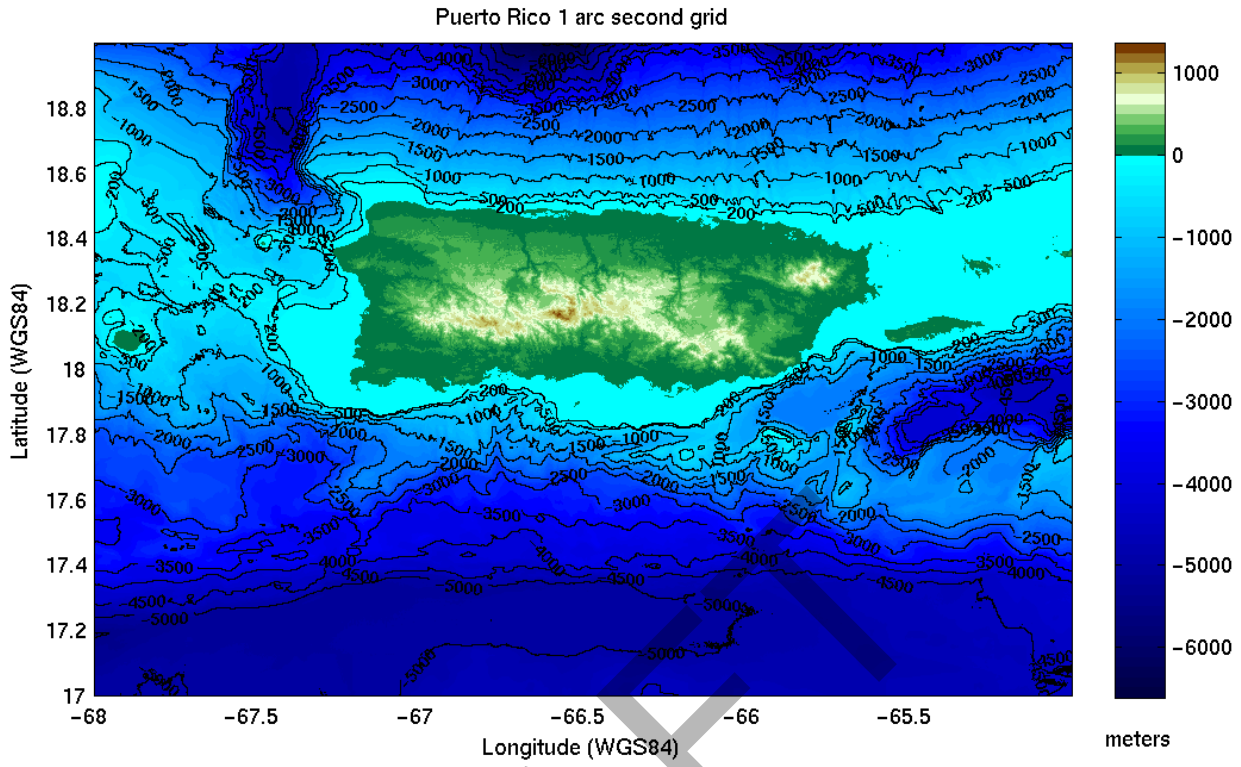

Figure 3 Depth contour plot of 3 arc sec grid supplied by NGDC. Note varying shelf width.

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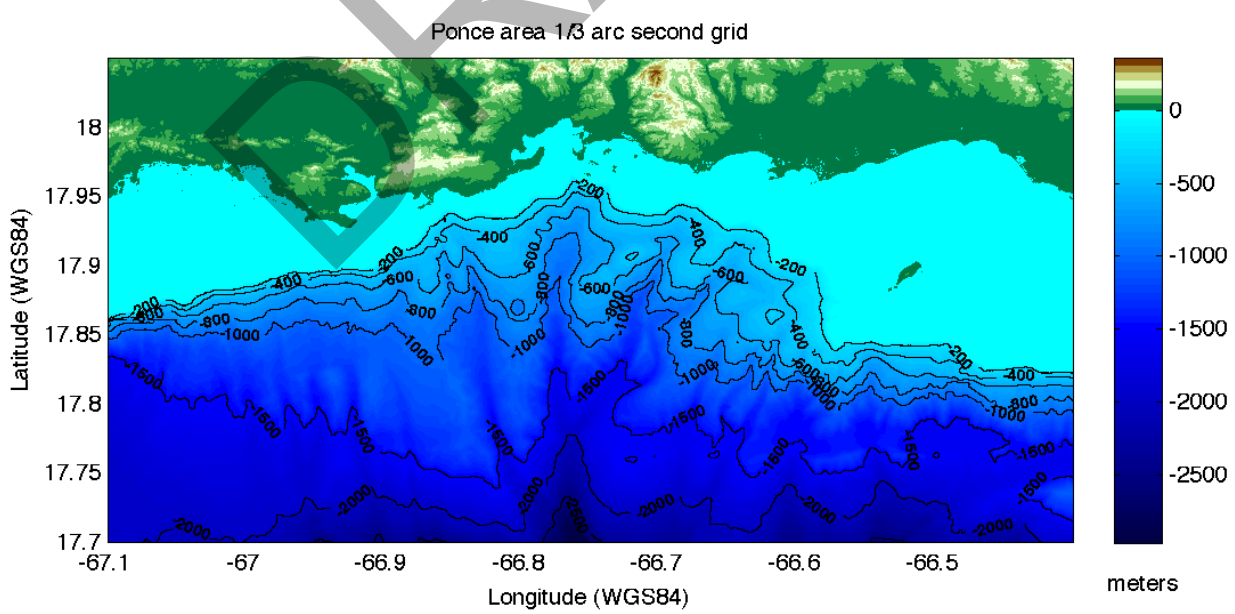

Figure 4 Depth contour plot of the high resolution (1/3 sec) grid supplied by NGDC for the Ponce metropolitan area. Note numerous islands and varying shelf width.

3.3 Tide gauges

The closest tide gauge to the Ponce Metropolitan area is located at Penuelas, west of the city. The gauge was established in March 2001 and its GPS validated location is 17 58.3' W and 66 45.7' N. The mean range is 0.66 feet and the diurnal range is 0.70 feet. Mean sea level for this location is 32.27 feet.

3.4 Reference Grids

There is no historical tsunami tide-gauge data for Ponce. Therefore it is important to maximize the accuracy of the reference grids by maintaining high resolution. Due to the complex bathymetry and extremely large tsunami sources employed, the resulting simulations were prone to instabilities. The instabilities were of two types: 1) those resulting in incomplete simulations (i.e., "crashing"); and 2) those that did not prematurely terminate the simulation, but resulting in an unphysical harmonic feedback (i.e., "ringing") of wave heights along the coast. Both situations responded well to judicious use of the Fortran routine 'bathcorr.f', as outlined in "Method of Splitting Tsunami (MOST) Software Manual" (NOAA/PMEL Tsunami Research Program).

Selected to cover the entire island, the 1 arc sec NGDC grid was re-sampled to 12 arc sec using Matlab (The Mathworks), as shown in Figure 5. Figure 5 also shows the outlines of Ponce grids B and C. This grid will be referred to as *PR12s_pass13.dat*, or A (reference; 12 s).

The 1/3 arc sec NGDC grid for south-central Puerto Rico was re-sampled to 6 arc sec and cropped using Matlab. Figure 6 shows the resulting reference Grid B for Ponce. Also shown is an outline of the reference Grid C for Ponce. To generate the reference grid C for Ponce, the 1/3 arc sec NGDC data for south-central Puerto Rico was re-sampled to 1 arc sec and cropped using Matlab. Figure 7 shows the resulting *P1s_C_pass2.dat*, or C (reference; 1 s), and Table 2 summarizes parameters for all the reference grids.

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	A	B	C
Lat	16.99986111-18.99958335	17.7000-18.04000	17.91000-18.02000
Long	65.00041664-68.00013889	66.470000 - 66.7700	66.5200-66.72000
ncols	900	181	721
nrows	600	205	397
Cellsize (arc sec)	18	6	1
X Grid spacing (degree)	0.00333333335999	0.00166666666667	0.0002777777699947137
Y Grid spacing (degree)	0.00333333336000	0.00166666666668	0.0002777777699982664
Zmin (m)	-6611.40	-2948.11	-719.73
Zmax (m)	1294.85	342.60	277.83
File name	*PR**12**s_pass13.dat*	*P6s_pass6.dat*	*P1s_C_pass2.dat*

Table 2 Summary of Reference grids for Ponce, Puerto Rico.

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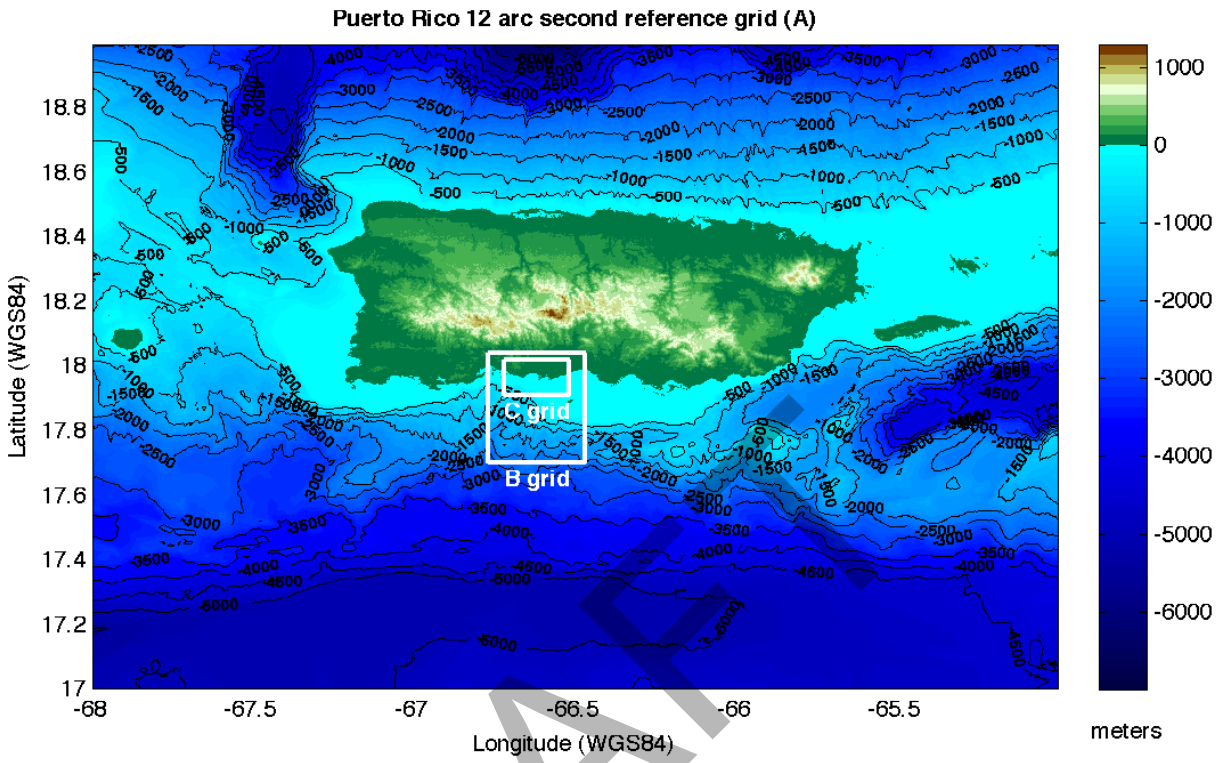

Figure 5 Depth contour plot of the common reference grid A (12 arc sec) to be used for Ponce. Reference grids B and C are superimposed in white.

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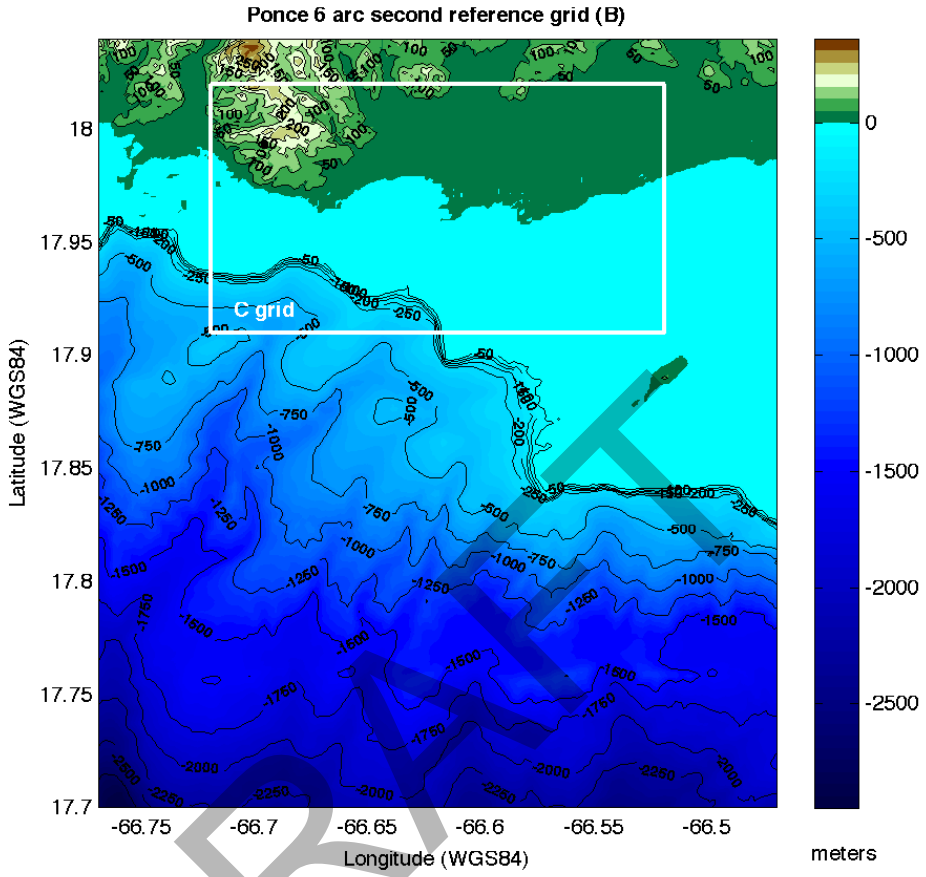

Figure 6 Depth contour plot of reference grid B, Ponce. Reference grid C is superimposed in white.

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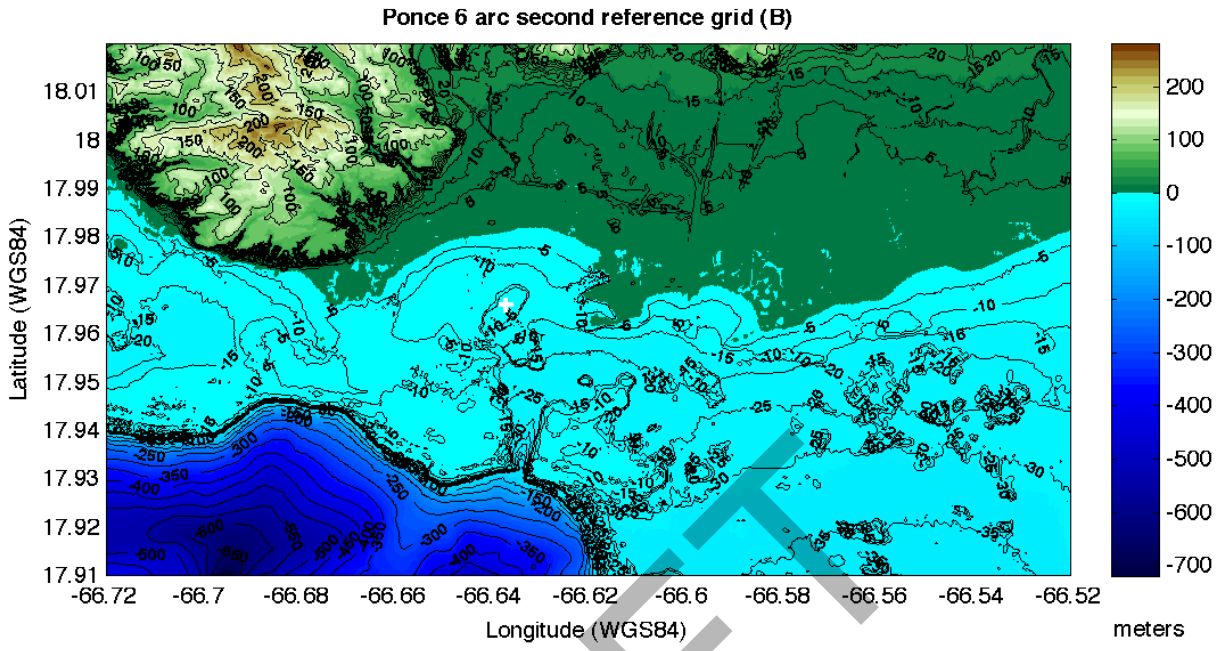

Figure7 Depth contour plot of reference grid C, Ponce. White cross denotes warning point location. Note complex bathymetry and local shoaling at warning point.

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The Ponce warning point coordinates used to test the SIM stability and sensitivity are 66.637 W, 17.966 N. This is where the tsunami time series of the reference versus the optimized grids will be compared. Figure 8 shows the approximate location of Ponce grid C in Google Earth.

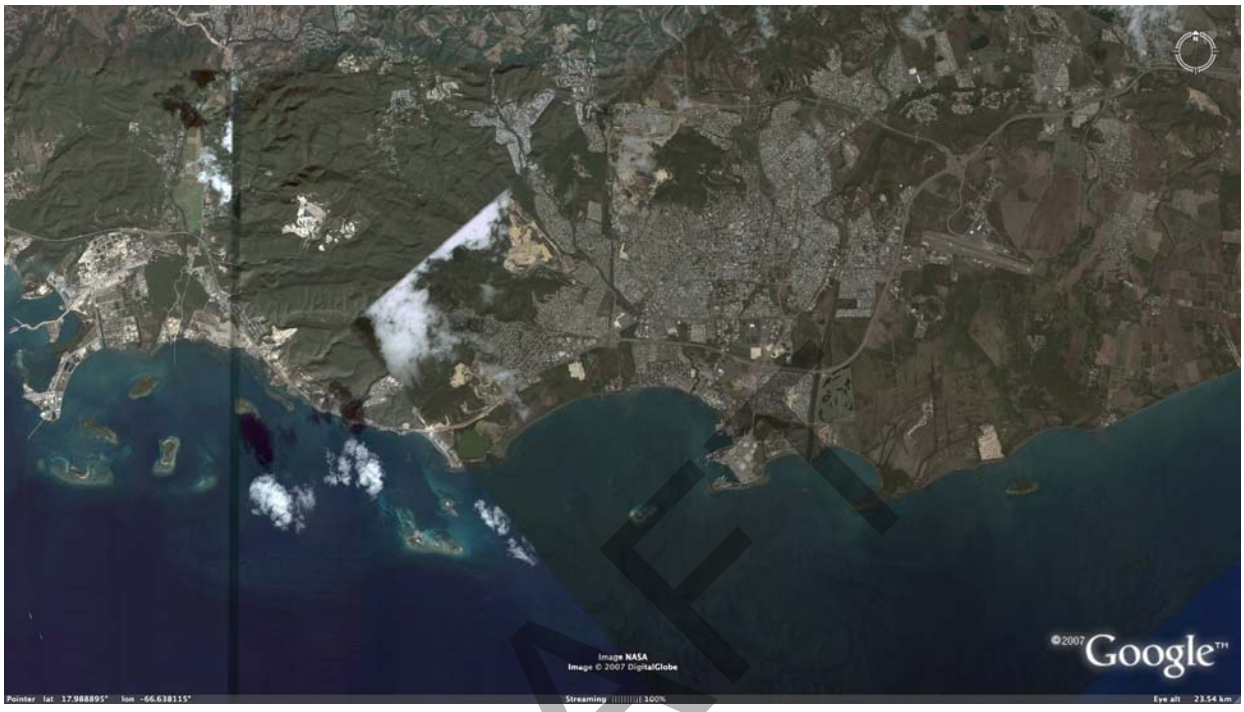

Figure 8 Google Earth view of Ponce, Puerto Rico C grid (approximate).

3.4 Optimized Grids

All computer simulations were run on a workstation with two AMD/Opteron 64-bits dual-coreCPU's and 8 GB of RAM. The operating system employed is Red Hat Enterprise Linux, and the 64-bit Fortran compiler is from the Portland Group.

The Ponce grids were tested against Muertos Trough sources south of the island, Lesser Antilles Trench sources east of the island, and South Caribbean Marginal Fault sources north of South America (Figure 2 and Table 1). Approximately 40 grid optimization attempts were made, with different versions of the optimized grids and simulation times. Table 8 shows the different grid versions and the CFL condition-based minimum time step for each. An arrow indicates the final time step utilized in Grid C. Whenever the time step for grid C became larger than that of grid B, the grid B time step was used.

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GRID A	DESCRIPTION	Δt (s)
PR12s_pass13.dat	12 arc sec reference grid A	1.3809
PR24s_pass3.dat	24 arc sec version of reference grid A	2.7686
PR36s_pass3.dat	36 arc sec version of reference grid A	4.1661
PR12s_A_cropped_pass13.dat	Cropped version of reference grid A with additional smoothing	1.8114
PR18s_A_cropped_pass12.dat	Cropped, 18 arc sec version of reference grid A	2.7171
GRID B		
P6s_pass6.dat	6 arc sec reference grid B	1.0399
P8s_pass2.dat	8 arc sec version of reference grid B	1.3867
P9s_pass1.dat	9 arc sec version of reference grid B	1.5641 ☐ 1.25
P6s_B_cropped_pass3.dat	Cropped version of reference grid B, no additional smoothing	1.7143 ☐ 1
GRID C		
P1s_C_pass2.dat	1 arc sec reference grid C	0.3504 ☐ 0.25
P3s_pass2.dat	3 arc sec version of the reference grid C	1.0688 ☐ 0.8
P1s_C_cropped_pass2.dat	Cropped version of reference grid C, no additional smoothing	2.2225 ☐ 1.25, 1

Table 3 Grids used during optimization attempts for Ponce.

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Snapshots were written to hard disk for all attempts, at a time interval of approximately 30 seconds. Also, a friction coefficient (n**2) of 0.0009 was used to reduce numerical instability in these worst-case scenarios.

The attempts simulated 4 hours for the goal of < 10 min CPU time per simulation. A quantitative method to assess the "goodness-of-fit" between the reference and optimized warning points time series became necessary since for Muertos Trough simulations became irregular and/or began to 'ring'. The root-mean-square (rms) difference between the optimized and the reference run was computed. Although combinations of grid resolution reduction and additional smoothing did result in optimized simulations that satisfied the goal of < 10 min CPU time, their resemblance to the reference simulations were poor, as judged visually and by rms difference. The ultimate solution in this case proved to be cropped versions of the original reference grids, with no change in resolution, except in the A grid which was reduced from 12 arc seconds to 18 arc seconds.

The resulting optimized grids then are:

A – (18 s) – *PR18s_A_cropped_pass12.dat*

B – (6 s) – *P6s_B_cropped_pass3.dat*

C – (1 s) – *P1s_C_cropped_pass2.dat*

Figures 9 through 11 show the optimized, cropped grids overlain on their respective reference grid. Basic details of the grids are given in Table 3.

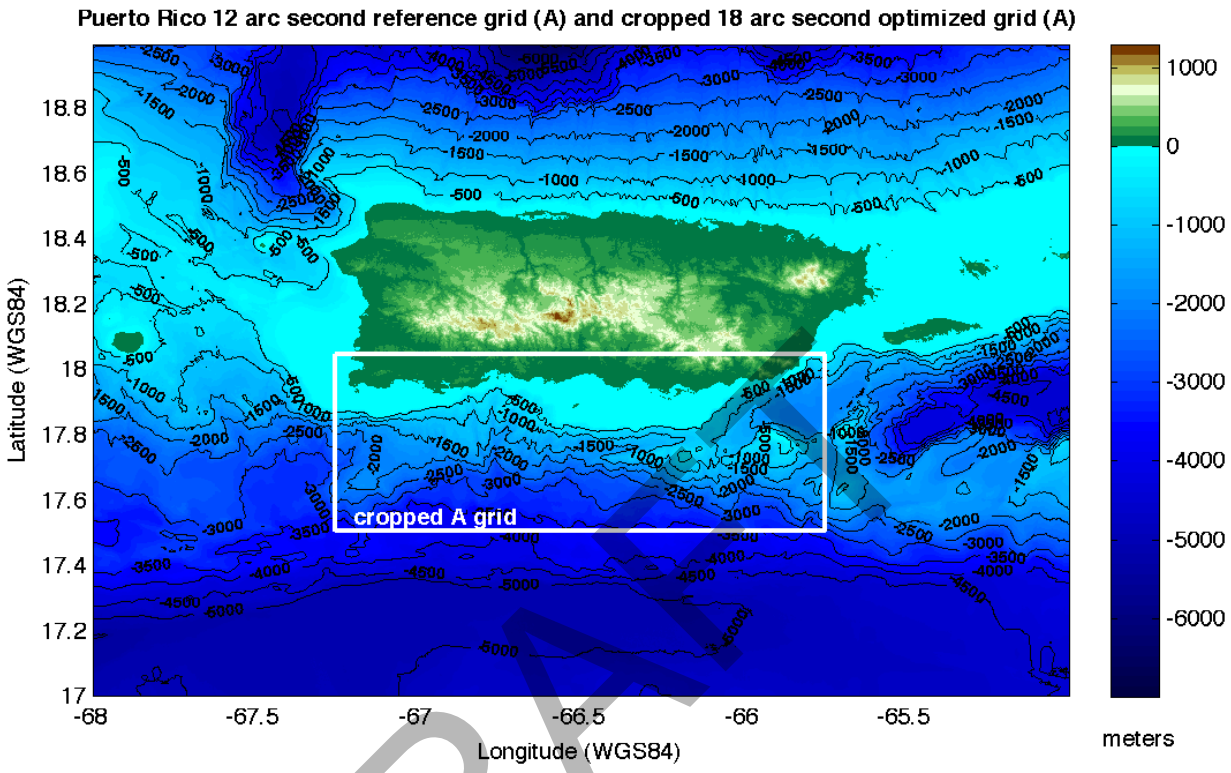

Figure 9 Depth contour plot of Puerto Rico 12 arc second reference grid A with extent of cropped Puerto Rico 18 arc second optimized grid A superimposed in white. Light blue line denotes 0 m elevation.

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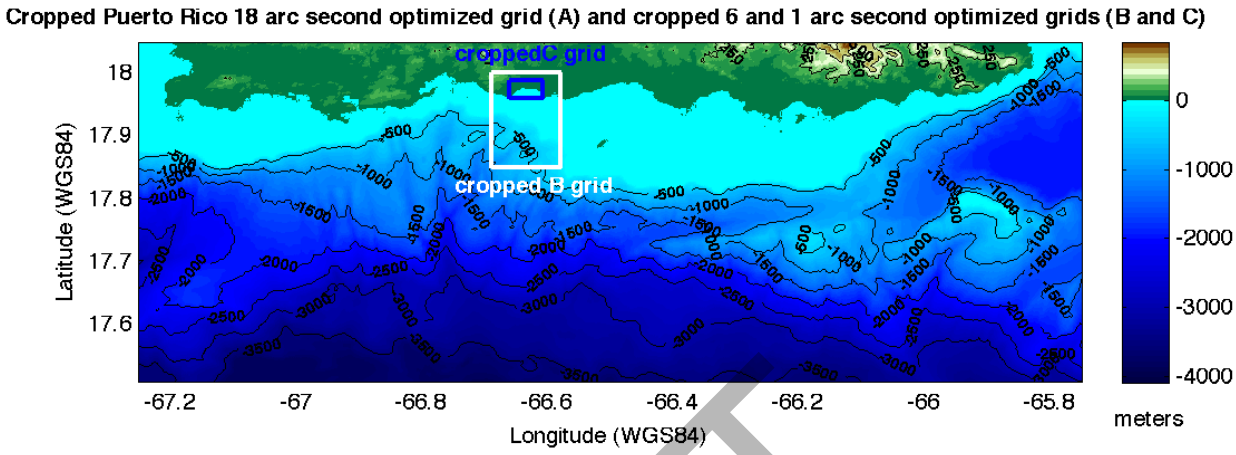

Figure 10 Depth contour plot of cropped Puerto Rico18 arc second optimized grid A with extent of cropped Ponce 6 arc second optimized grid B superimposed in white and extent of cropped Ponce 1 arc second optimized grid C superimposed in blue.

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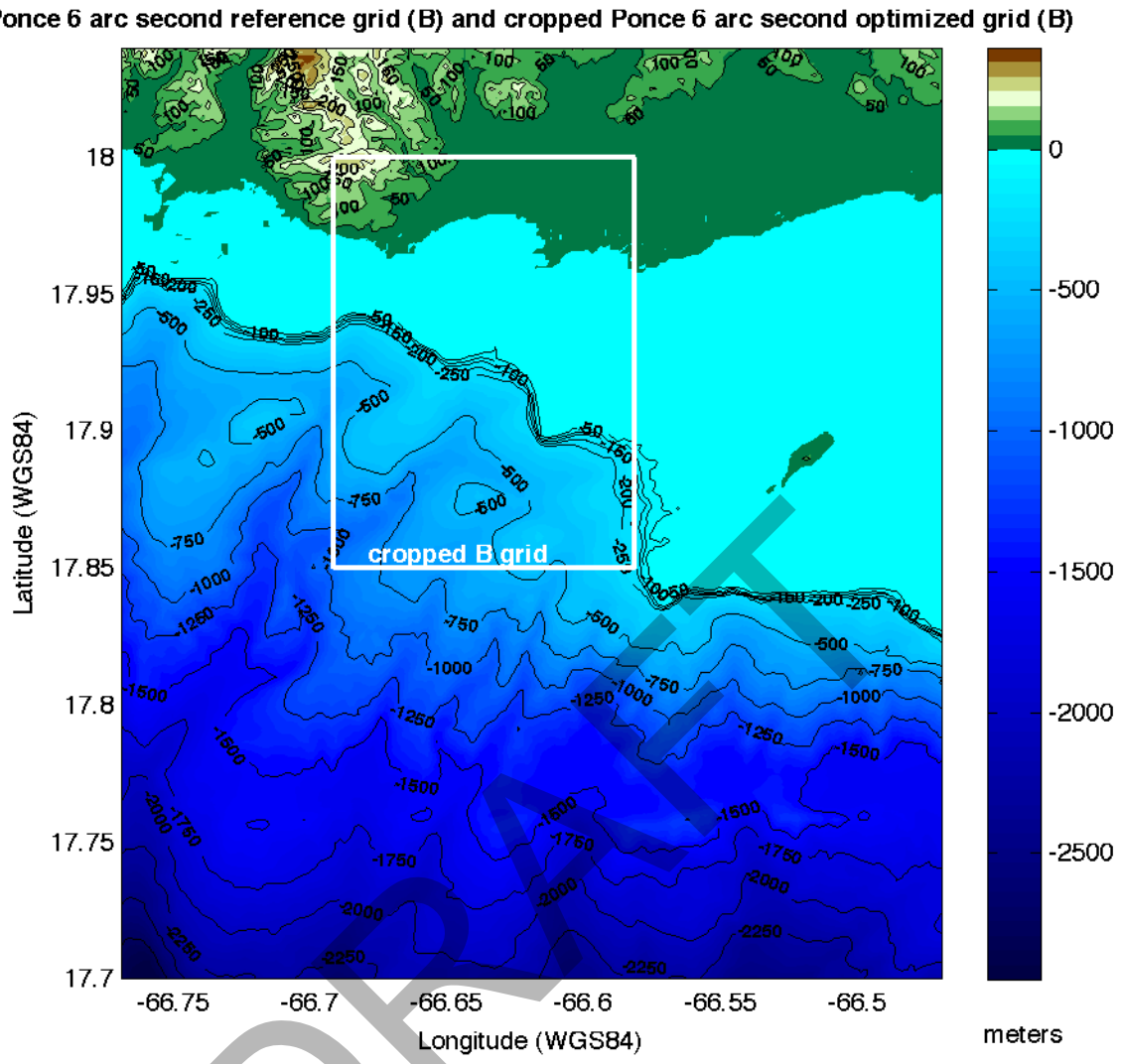

Figure 11 Depth contour plot of Ponce 6 arc second reference grid B with extent of cropped Ponce 6 arc second optimized grid B superimposed in white.

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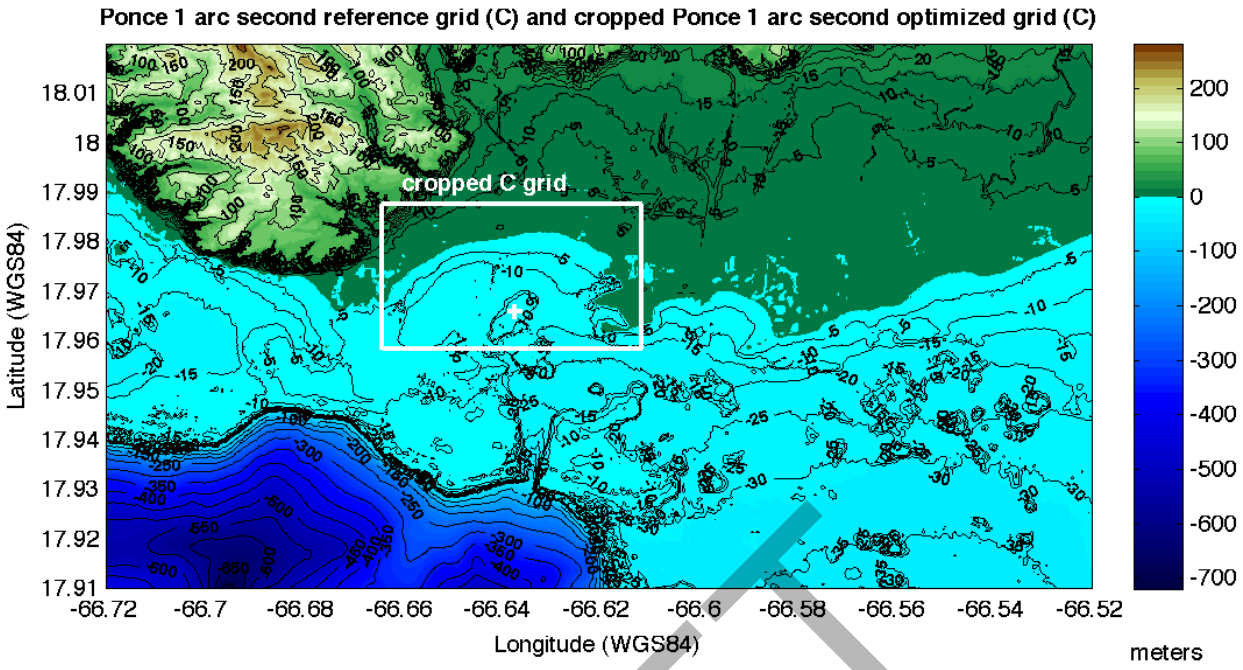

Figure 12 Depth contour plot of Ponce 1 arc second reference grid C with extent of cropped Ponce 1 arc second optimized grid C superimposed in blue. White cross denotes warning point location. Note complex bathymetry and local shoaling at warning point.

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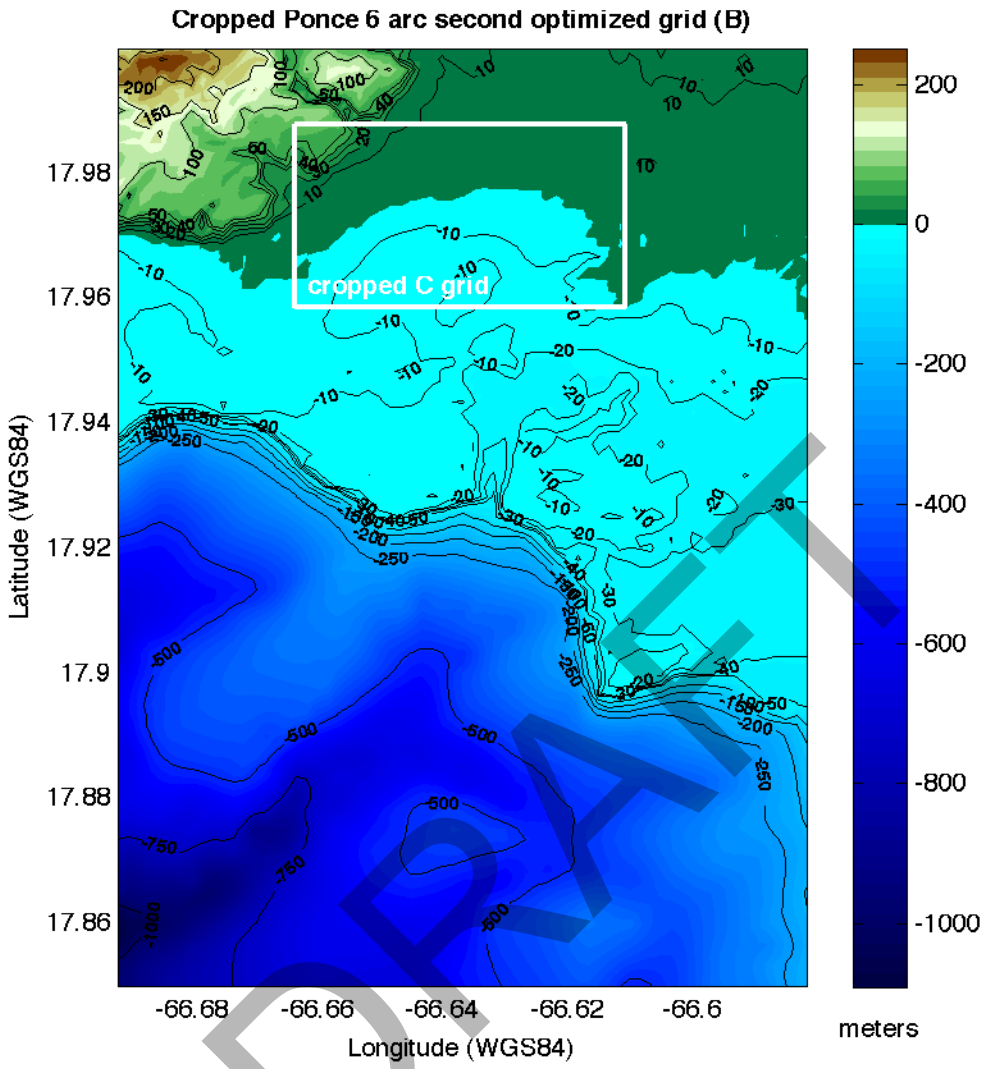

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Figure 13 Depth contour plot of cropped Ponce 6 arc second optimized grid B with extent of cropped Ponce 1 arc second optimized grid C superimposed in white.

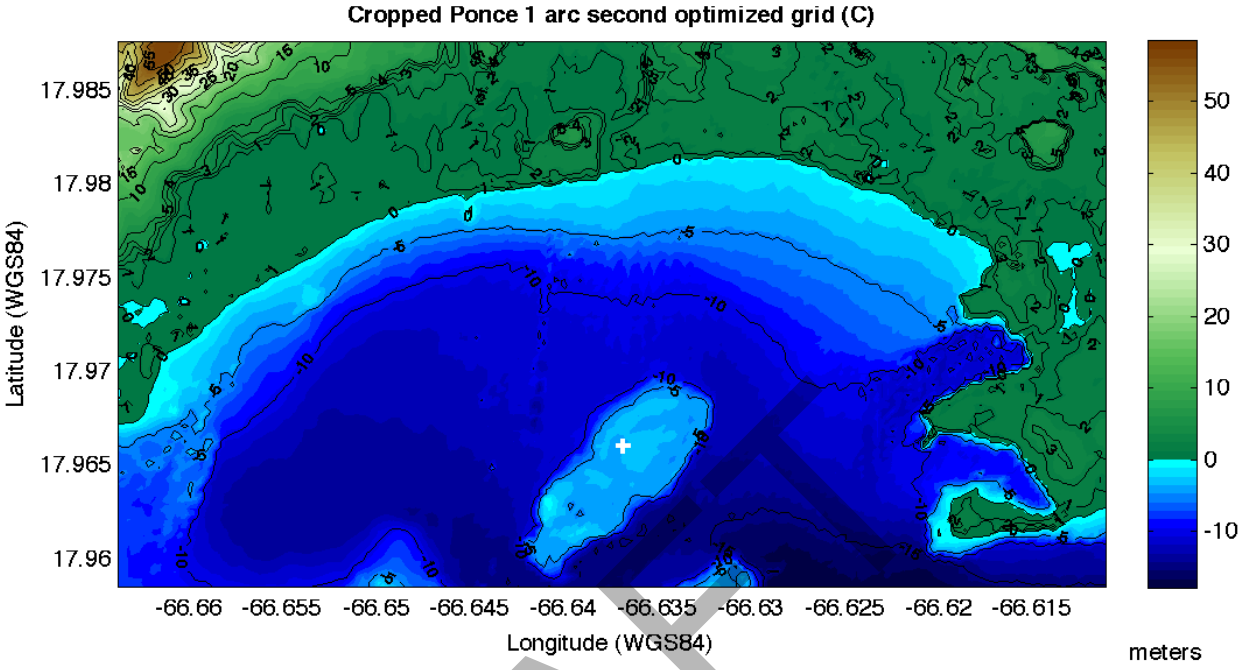

Figure 14 Depth contour plot of cropped Ponce 1 arc second optimized grid C. Note complex bathymetry.

4.0 Results

Figure 15 shows 4 hours of Muertos Trough source simulation for reference and optimized grids and the entire 10 hour reference simulation. Evident at the simulation start is an approximately -1.42 m co-seismic deformation owing to Ponce's proximity to the extremely large Muertos Trough Source. Figures 16 and 17 show the Lesser Antilles Trench and the South Caribbean Marginal Fault sources, respectively. It can be seen these sources further south and east of the island still pose a tsunami threat to Ponce.

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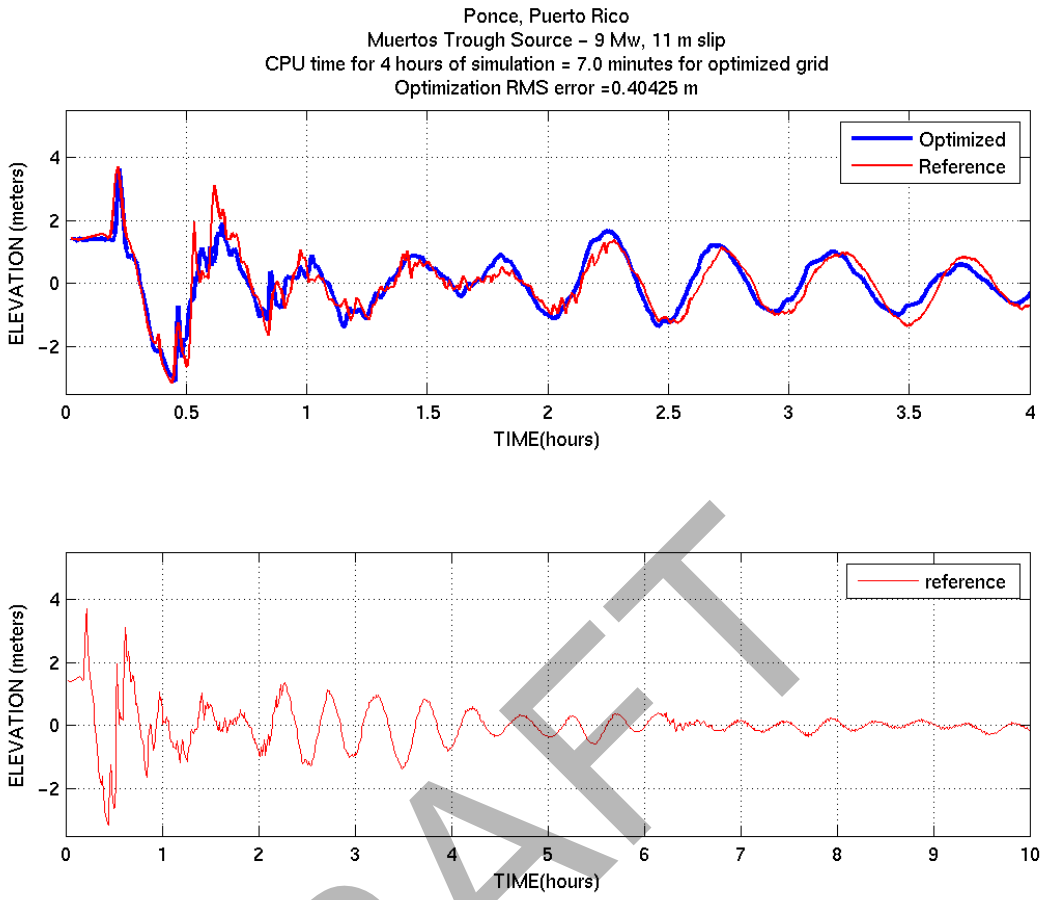

Figure 15 Time series at warning point, Ponce, for Muertos Trough source. Red line is for reference grids. Blue line is for optimized grids. Top: Comparison, first 4 hours of simulation. Bottom: 10 hours of simulation, reference only.

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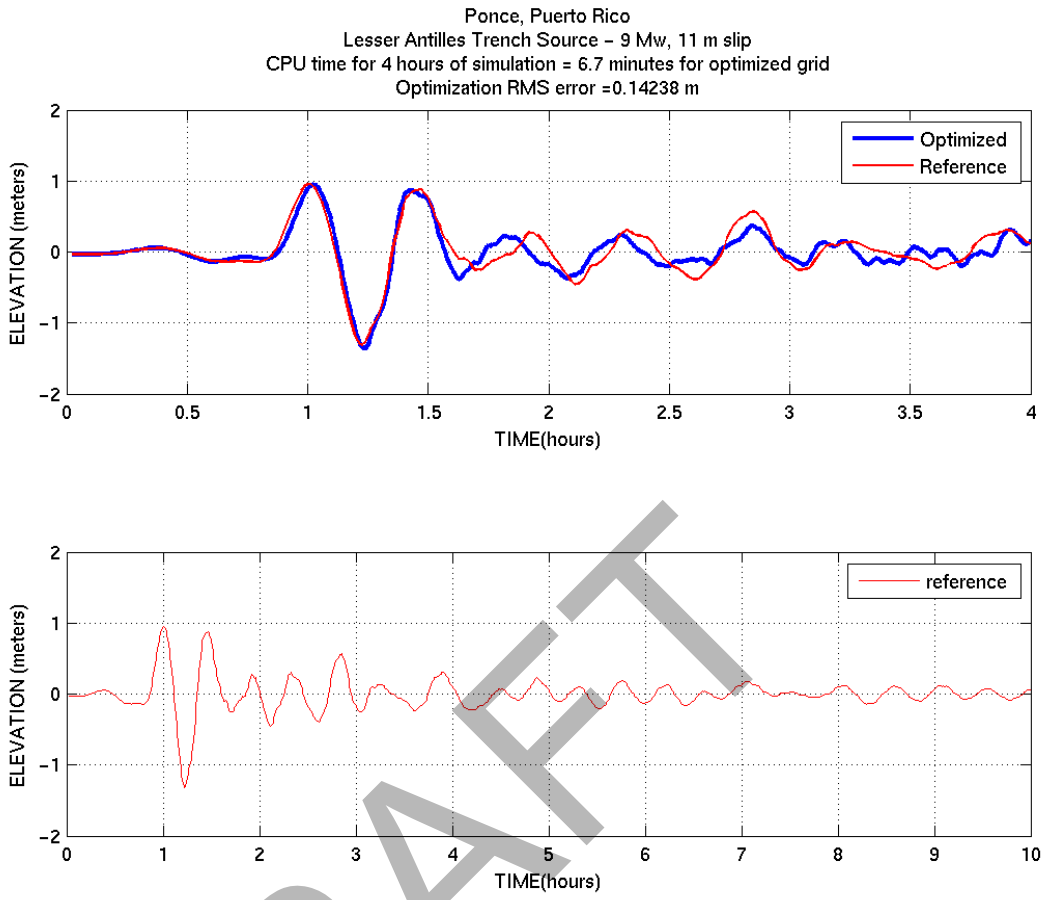

Figure 16 Time series at warning point, Ponce, for Lesser Antilles Trench source. Red line is for reference grids. Blue line is for optimized grids. Top: Comparison, first 4 hours of simulation. Bottom: 10 hours of simulation, reference only

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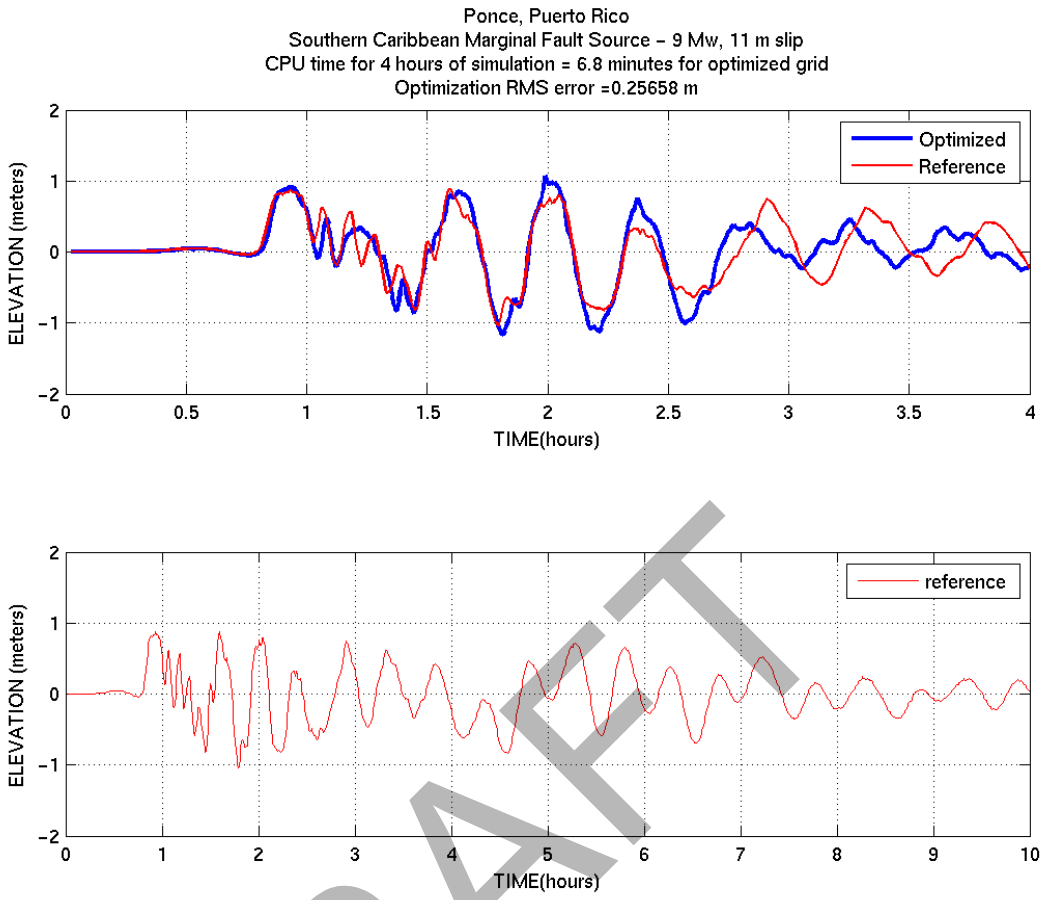

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Figure 17 Time series at warning point, Ponce, for South Caribbean Marginal Fault source. Red line is for reference grids. Blue line is for optimized grids. Top: Comparison, first 4 hours of simulation. Bottom: 10 hours of simulation, reference only.

Figures 18 - 20 compare maximum sea-surface elevation (MSSE) in both the reference and optimized grid C for Muertos Trough sources, Lesser Antilles Trench, and South Caribbean Marginal Fault respectively. It can be concluded that, as expected, a large tsunami generated at the Muertos Trough offers a great threat to Ponce. In fact, the event simulated cause a -1.42 m co-seismic displacement in the Warning Point area. Large events originating in the Lesser Antilles Trench and South Caribbean Marginal Fault also present significant threats. From the equivalent figures for grids B and A (Figures 21 - 23 and 24-26 respectively), it can also be concluded that these threats exists all along the south coast of the island. The final RIM and SIM parameters for Ponce, Puerto Rico are summarized in Table 4.

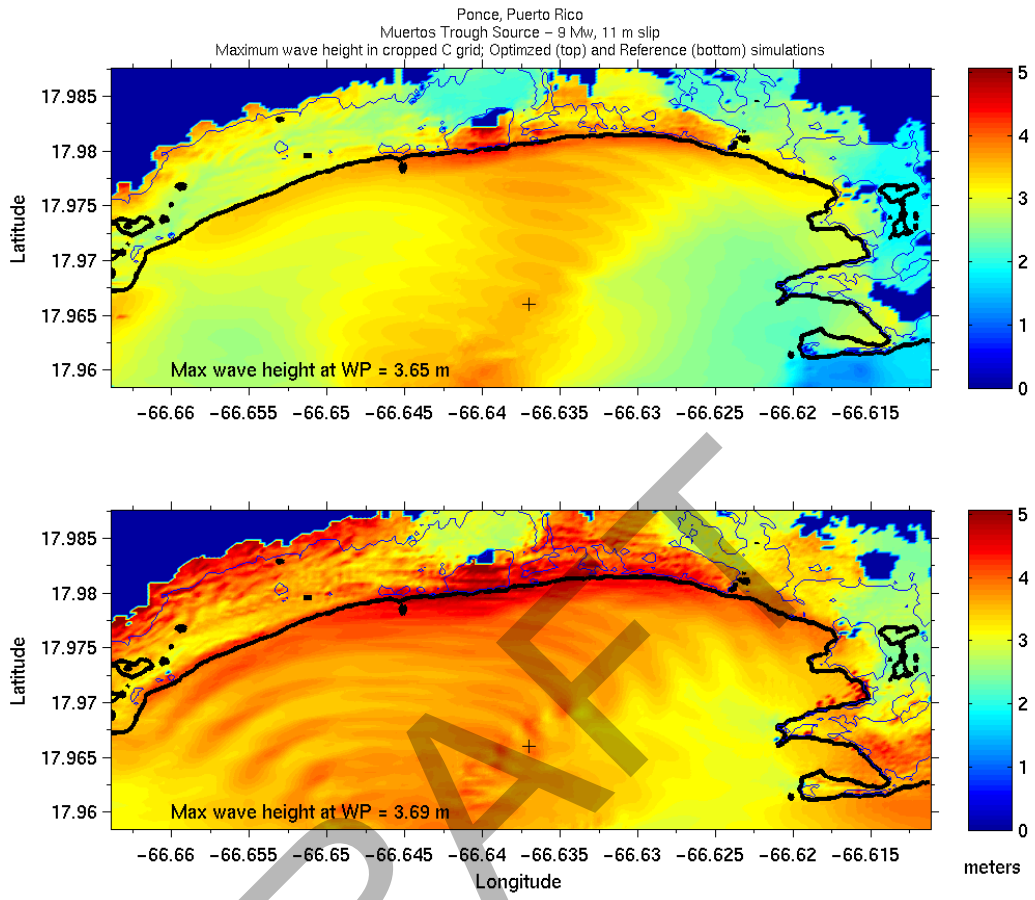

Figure 18 Maximum sea surface elevation for Ponce optimized grid C (top) vs. reference grid C (bottom), Muertos Trough sources. Simulation time for optimized grid, 4 hours; reference grid, 10 hours. Thick black line indicates 0 m elevation prior to co-seismic deformation. Thin blue line indicates vertical extent of co-seismic deformation (-1.42 m). Black cross denotes location of warning point.

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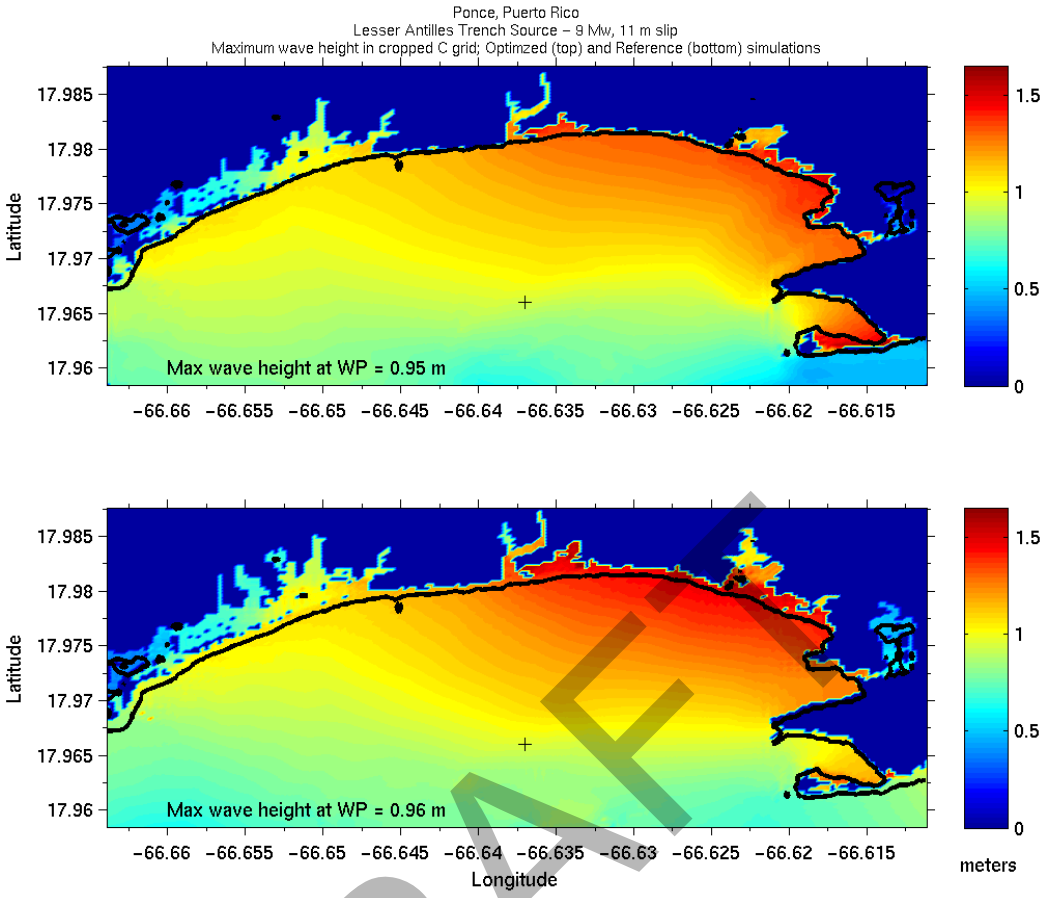

Figure 19 Maximum sea surface elevation for Ponce optimized grid C (top) vs. reference grid C (bottom), Lesser Antilles Trench sources. Simulation time for optimized grid, 4 hours; reference grid, 10 hours. Thick black line indicates 0 m elevation. No co-seismic deformation was observed in these simulations. Black cross denotes location of warning point.

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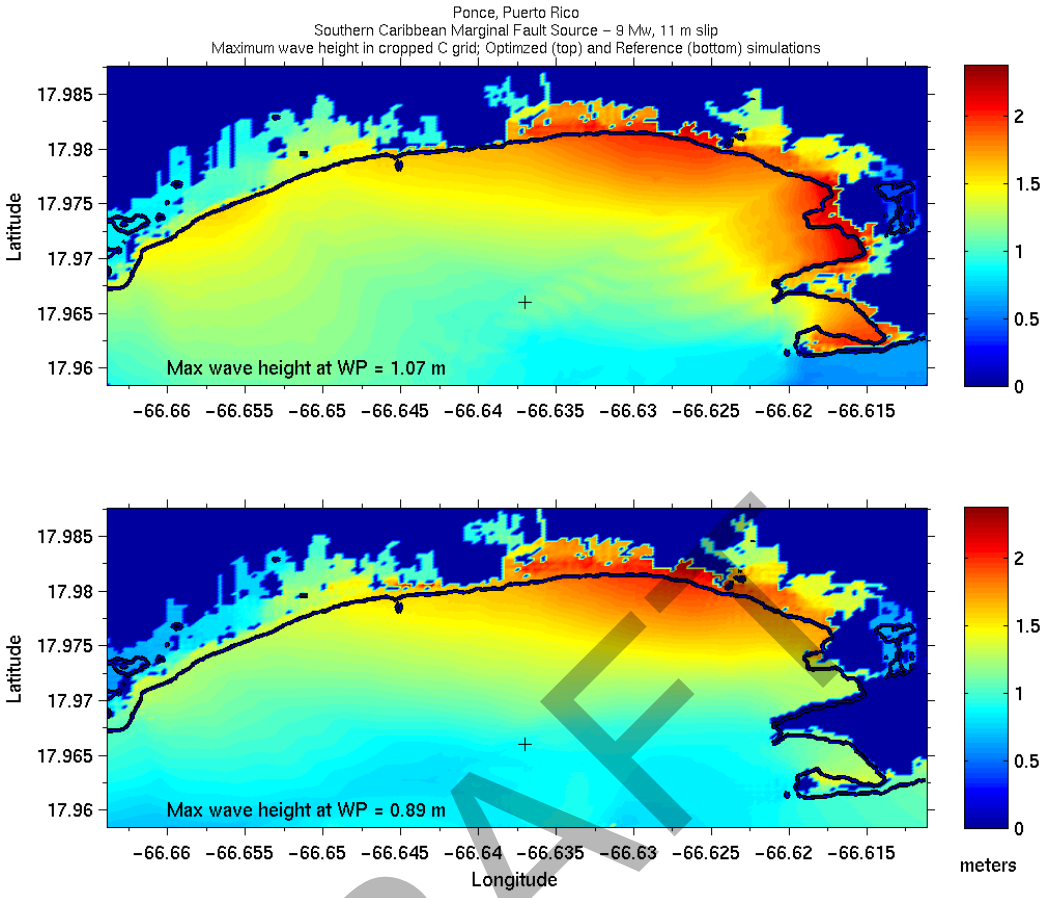

Figure 20 Maximum sea surface elevation for Ponce optimized grid C (top) vs. reference grid C (bottom), Southern Caribbean Marginal Fault sources. Simulation time for optimized grid, 4 hours; reference grid, 10 hours. Thick black line indicates 0 m elevation. No co-seismic deformation was observed in these simulations. Black cross denotes location of warning point.

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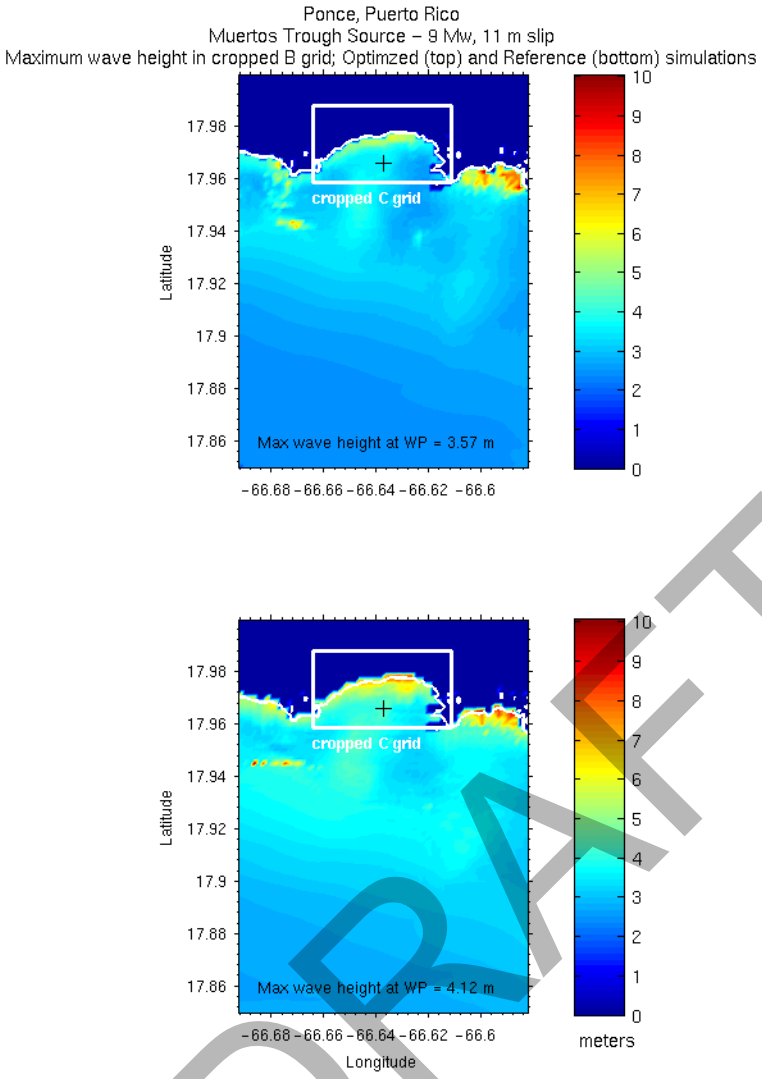

Figure 21 Maximum sea surface elevation for optimized grid B (top) vs. reference grid B (bottom), Muertos Trough sources. Simulation time for reference grid was 10 hours; optimized grid, 4 hours. Extent of optimized cropped grid C outlined in white. Thin white line indicates 0 m elevation prior to co-seismic deformation. Black cross denotes location of warning point.

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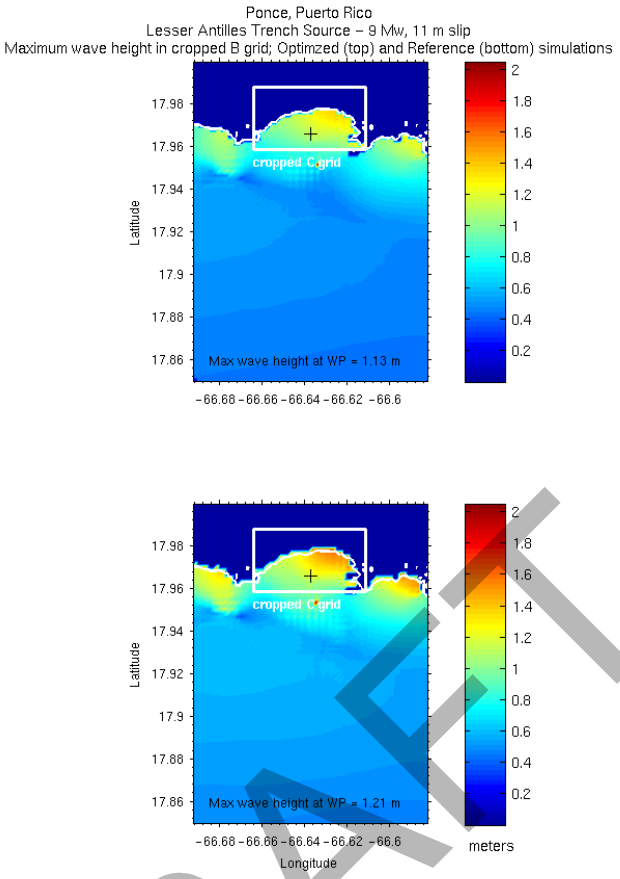

Figure 22 Maximum sea surface elevation for optimized grid B (top) vs. reference grid B (bottom), Lesser Antilles Trench sources. Simulation time for reference grid was 10 hours; optimized grid, 4 hours. Extent of optimized cropped grid C outlined in white. Thin white line indicates 0 m elevation. Black cross denotes location of warning point.

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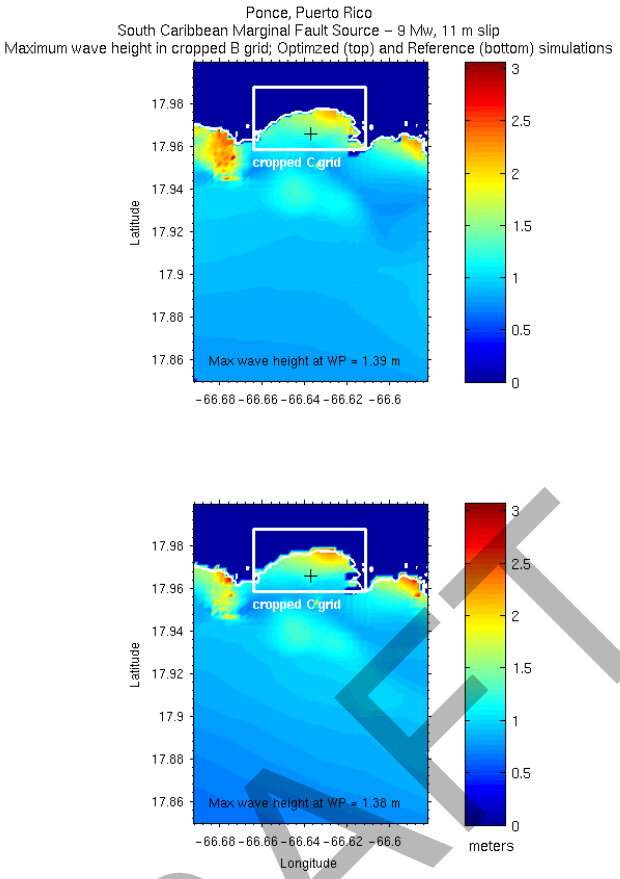

Figure 23 Maximum sea surface elevation for optimized grid B (top) vs. reference grid B (bottom), Southern Caribbean Marginal Fault sources. Simulation time for reference grid was 10 hours; optimized grid, 4 hours. Extent of optimized cropped grid C outlined in white. Thin white line indicates 0 m elevation. Black cross denotes location of warning point.

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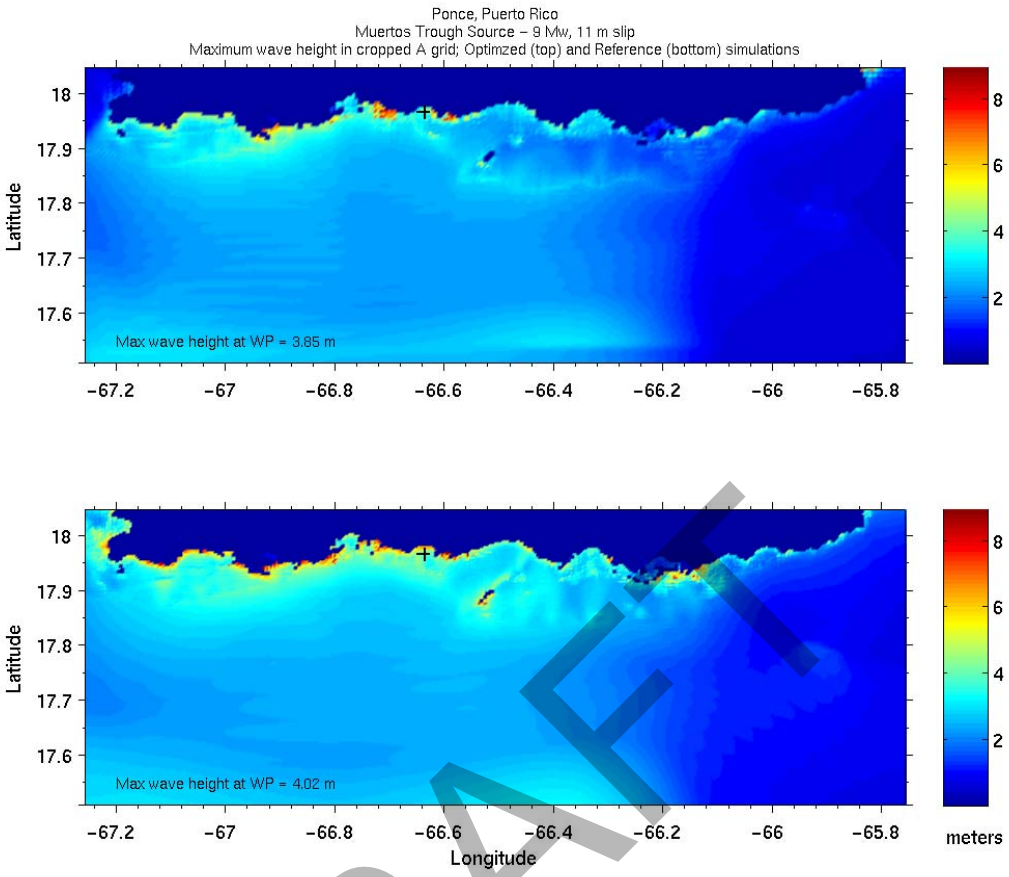

Figure 24 Maximum sea surface elevation for optimized grid A (top) vs. reference grid A (bottom), Muertos Trough sources. Simulation time for reference grid was 10 hours; optimized grid, 4 hours. Black cross denotes location of warning point.

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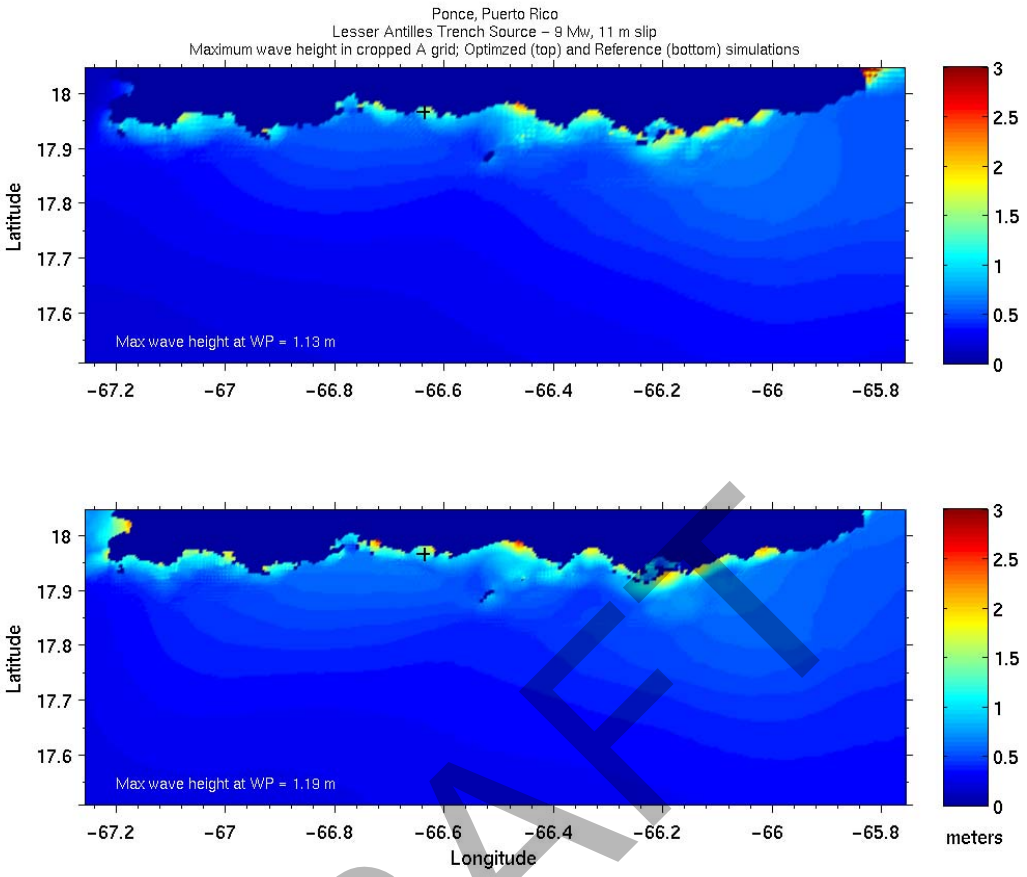

Figure 25 Maximum sea surface elevation for optimized grid A (top) vs. reference grid A (bottom), Lesser Antilles Trench sources. Simulation time for reference grid was 10 hours; optimized grid, 4 hours. Black cross denotes location of warning point.

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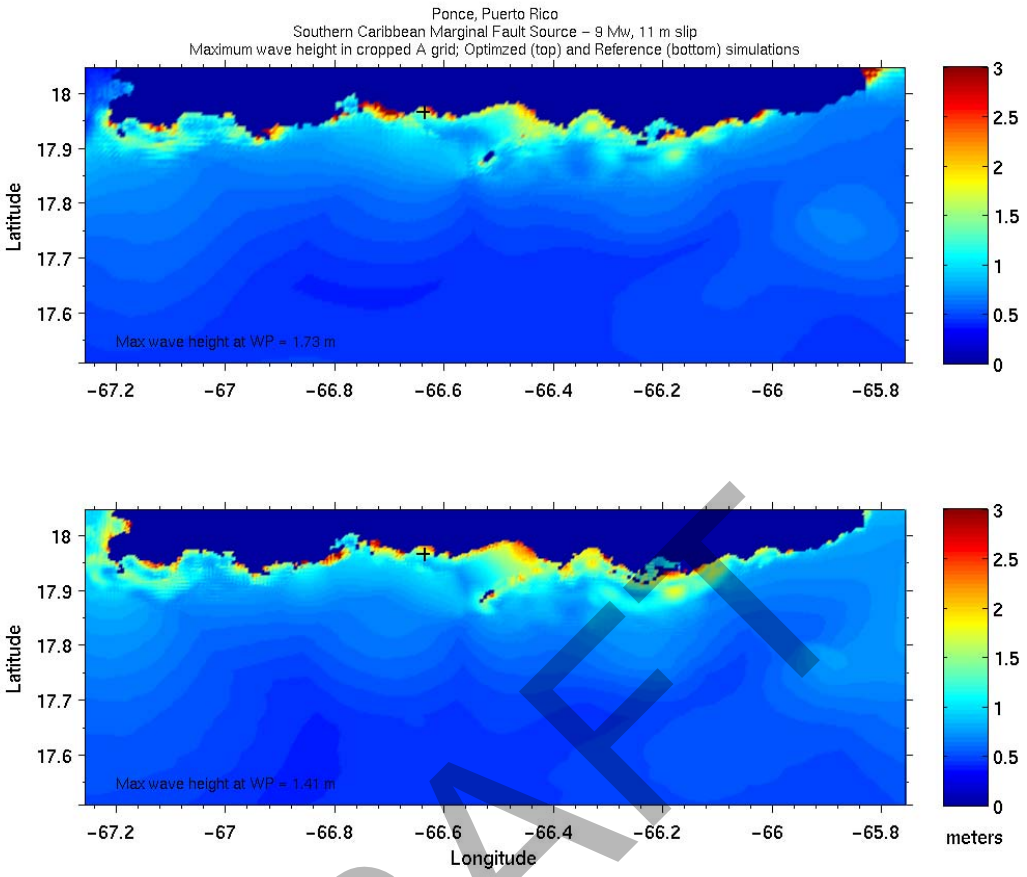

Figure 26 Maximum sea surface elevation for optimized grid A (top) vs. reference grid A (bottom), Southern Caribbean Marginal Fault sources. Simulation time for reference grid was 10 hours; optimized grid, 4 hours. Black cross denotes location of warning point.

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Grid	Region	Reference Inundation Model (RIM)				Stand-by Inundation Model (SIM)		
		Coverage	**Cell**	**Time**		**Coverage**	**Cell**	**Time**
		Lat. [°N]	**Size**	**Step**		**Lat. [°N]**	**Size**	**Step**
		Lon. [°W]	**["]**	**[sec]**		**Lon. [°W]**	**["]**	**[sec]**
A	Puerto Rico	16.99986111- 18.99958334 68.00013889 65.00041664	12	1.3809		17. 5080117 -18. 0495763 67.2557400- 65.7526727	18	2.717
			(900x600)				(452x163) (1)	
B	Ponce	17.700- 18.040 66.770 -66.470	6	1.0399		17.8498796- 17.9998027 66.6922179 - 66.5826483	6	1.7143
			(181x205)				(67x91)(2)	
C	Ponce	17.910-18.020	1	0.3504		17.9584796 - 17.9876148 66.6639300 - 66.6112681	1	2.225
		66.720-66.520	(721x397)			67.222-67.137 (2)	(191x106)(3)	
Minimum offshore depth [m]			0			0		
Water depth for dry land [m]			0.1			0.1		
Manning coefficient			0.0009			0.0009		
CPU time for a 4-hour simulation			>214 min			**< 10 minutes**		

DRAFT

Table 4 MOST set up of reference and optimized models for Ponce, Puerto Rico.

5.0 Conclusions

A Standby Inundation Models (SIM) has been developed for the city of Ponce on the island of Puerto Rico. The results presented show that the city and surrounding area is vulnerable to tsunamis originating in Muertos Trough and South Caribbean Marginal Fault, south of the island, and the Lesser Antilles Trench, east of the island. Appendix 1 shows sample *.in and *.lis files for Ponce (both for the reference and optimized runs).

6.0 Acknowledgements

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The introductory material of this document was taken from the draft of the report by L. Tang, C. Chamberlin, and V.. Titov "A Standby Inundation Model of Kahului, Hawaii, for NOAA Short-Term Inundation Forecasting for Tsunamis (SIFT)", March 2006.

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Appendix 1

Ponce Reference Grids *.in file

```
0.001    Minimum amplitude of input offshore wave (m):
0        Input minimum depth for offshore (m)
0.1      Input "dry land" depth for inundation (m)
0.0009   Input friction coefficient (n**2)
1        let a and b run up
200.0    max eta before blow up (m)
0.25     Input time step (sec)
144000   Input amount of steps
4        Compute "A" arrays every n-th time step, n=
3        Compute "B" arrays every n-th time step, n=
120      Input number of steps between snapshots (60 sec)
0        ...Starting from
1        ...Saving grid every n-th node, n=
```

DRAFT

Ponce Reference Grids *.lis file

```
9-05-2007  16:50:19.407
 Site:  3P_MT_10hr_r
 Input prefix:  26441
 Input Directory:  ./
 Read Computational parameters: ./most3_facts_nc.in_
  Minimum amplitude of input offshore wave (m):   1.0000000000000000E-003
  Input minimum depth for offshore (m):     0.000000000000000
  Input "dry land" depth for inundation (m):    0.1000000000000000
  Input friction coefficient (n**2):    9.0000000000000000E-004
  Input runup switch (0 - runup only in gridC, 1 - runup in all grids):            1
  Max allowed eta (m):     200.0000
  Input time step (sec):    0.2500000000000000
  Input amount of steps:        144000
  Compute "A" arrays every n-th time step, n=           4
  Compute "B" arrays every n-th time step, n=           3
  Input number of steps between snapshots (should be a    multiple of A,B and C time steps) :           120
  ...Starting from:             0
  ...Saving grid every n-th node, n=           1
 Reading Bathymetry
   1-ST LEVEL:
 Bathymetry:  ./PR12s_pass18.dat
   2-ND LEVEL:
 Bathymetry:  ./P6s_pass6.dat
   3-RD LEVEL:
 Bathymetry:  ./P1s_C_pass2.dat
  DODS URL:  /home2/wschmidt/1Ponce/ASOURCES/
  Input FACTS files:
size of input array:           23          16          1441
  Longitude:    291.0333000000000       to    296.8999666666667
   Latitude:    16.10000000000000       to    20.10000000000000
       Time:    0.000000000000000       to    86400.00000000000
 NetCDF array size for grid C:          721          397
 NetCDF array size for grid B:          181          205
 NetCDF array size for grid A:          900          600

input           2  wave detected at    60.00000000000000       amp:
    59.26966476440430      cm at     292.0999666666667       ,
    17.16667000000000
 Initial surface is read at t=    60.00000000000000
  Run finished

   9-06-2007   2:05:11.723
  elapsed secs:    33270.79     , user:    33200.58     , sys:    70.21000
  clock sec:        33292 , minutes:    554.8667
```

DRAFT

Ponce Optimized Grids *.in file

```
0.001    Minimum amplitude of input offshore wave (m):
0        Input minimum depth for offshore (m)
0.1      Input "dry land" depth for inundation (m)
0.0009   Input friction coefficient (n**2)
1        let a and b run up
200.0    max eta before blow up (m)
1        Input time step (sec)
14400    Input amount of steps (4 hrs)
2        Compute "A" arrays every n-th time step, n=2
1        Compute "B" arrays every n-th time step, n=1
20       Input number of steps between snapshots (60 sec)
0        ...Starting from
1        ...Saving grid every n-th node, n=
```

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Ponce Optimized *.lis file

```
9-06-2007  16:24:40.663
 Site:  2P_MT_4hr_o
 Input prefix:  26441
 Input Directory:  ./
 Read Computational parameters: ./most3_facts_nc.in_
  Minimum amplitude of input offshore wave (m):   1.0000000000000000E-003
  Input minimum depth for offshore (m):     0.000000000000000
  Input "dry land" depth for inundation (m):    0.1000000000000000
  Input friction coefficient (n**2):    9.0000000000000000E-004
  Input runup switch (0 - runup only in gridC, 1 - runup in all grids):            1
  Max allowed eta (m):     200.0000
  Input time step (sec):     1.000000000000000
  Input amount of steps:          14400
  Compute "A" arrays every n-th time step, n=            2
  Compute "B" arrays every n-th time step, n=            1
  Input number of steps between snapshots (should be a    multiple of A,B and C time steps) :            20
  ...Starting from:             0
  ...Saving grid every n-th node, n=            1
 Reading Bathymetry
  Input FACTS files:
size of input array:           23           16          1441
  Longitude:    291.0333000000000       to    296.8999666666667
   Latitude:    16.10000000000000       to    20.10000000000000
       Time:    0.000000000000000       to    86400.00000000000
 NetCDF array size for grid C:           191          106
 NetCDF array size for grid B:            67           91
 NetCDF array size for grid A:           301          109
  output directory:  /home2/wschmidt/1Ponce/2Ponce_MT_4hr_opt/Output/
input            2  wave detected at    60.00000000000000       amp:
    161.1797485351563      cm at     292.8999666666667       ,
    17.70000000000000
 Initial surface is read at t=    60.00000000000000
  Run finished

   9-06-2007  16:31:40.863
  elapsed secs:    419.4300     , user:    416.4500     , sys:    2.980000
  clock sec:          420 , minutes:    7.000000
```

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