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The 1755 Lisbon Tsunami in Guadeloupe Archipelago: Source Sensitivity and Investigation of Resonance Effects

J. Roger*[,1,2], S. Allgeyer[2,3], H. Hébert[2], M.A. Baptista[1], A. Loevenbruck[2], F. Schindelé[2]

[1]*Centro de Geofisica da Universidade de Lisboa, Rua Ernesto de Vasconcelos, Faculdade de Ciències Ed. C8, 6°, 1700 Lisboa, Portugal;* [2]*CEA, DAM, DIF, F-91297 Arpajon, France;* [3]*Ecole Normale Supérieure / Laboratoire de Géologie, 24, rue Lhomond, 75231 Paris CEDEX 5, France*

Abstract: On the 1st of November 1755, a major earthquake of estimated Mw=8.5/9.0 destroyed Lisbon (Portugal) and was felt in whole Western Europe. It generated a huge tsunami which reached coastlines from Morocco to Southwestern England with local run-up heights up to 15 m in some places as Cape St Vincent (Portugal). Important waves were reported in Madeira Islands and as far as in the West Indies where heights of 3 m and damages are reported. The present knowledge of the seismic source(s), presented by numerous studies, was not able to reproduce such wave heights on the other side of the Atlantic Ocean whatever the tested source. This could be due to the signal dispersion during the propagation or simply to the lack of simulations with high resolution grids. Here we present simulations using high resolution grids for Guadeloupe Archipelago for two different sources. Our results highlight important wave heights of the range of 1 m to more than 2 m whatever the source mechanism used, and whatever the strike angle in some particular coastal places.

A preliminary investigation of the resonance phenomenon in Guadeloupe is also presented. In fact, the studies of long wave impact in harbours as rissaga phenomenon in the Mediterranean Sea leads us to propose the hypothesis that the 1755 waves in the West Indies could have been amplified by resonance phenomenon.

Most of the places where amplification takes place are nowadays important touristic destinations.

Keywords: Tsunami, modelling of the wave propagation in Atlantics, 1755 Lisbon earthquake, Lesser Antilles, wave resonance.

1. INTRODUCTION AND HISTORICAL SETTINGS

Strong magnitude tsunamis are relatively infrequent in the Atlantic Ocean. There are two different areas prone to tsunami generation: the western end of the Eurasia – Nubia (EN) plate boundary east of 19°W – in the North East Atlantic area and the Caribbean subduction zone in the West Central Atlantic area.

In this study we focus in the area corresponding to the western segment of the EN plate boundary east of 19ºW. This area is morphologically complex, characterized by seamounts (the Gorringe Bank, the Coral Patch and Ampère seamounts) that delimitate the abyssal plains: Horseshoe and Tagus (Fig. **1**). where discrete segments of plate boundary are hard to identify [1, 2]. The seismicity and the focal mechanisms computed for the main earthquakes do not solve clearly the problem of location of the interplate domain east of 19°W [3]. The focal mechanisms [4, 5] indicate right lateral and reverse faulting on roughly east - west oriented structures. This is usually interpreted as the result of the relatively low inter-plate motion (ca. 4 mm/y) given by kinematic plate models (e.g. [6-8]).

This slow convergence rate may be the explanation for the fact that strong tsunamis are infrequent events in this area. In fact large subduction zones with high convergence rates seem to be mainly responsible for the generation of huge tele-tsunamis [9].

However in the last 300 years there are several events reported with origin in the North Atlantic area. The most important submarine earthquakes are the events of the Gloria Fault-Azores (M 7.9, 1975.05.26), Horseshoe Abyssal Plain (M 7.9, 1969.02.28), Madeira-Azores (M 8.2, 1941.11.25), Grand Banks (M 7.2 + large submarine slump, 1929.11.18), North Atlantic-Azores (1761.03.31) and Lisbon (1755.11.1) [10], with variations of geodynamical context. Some of them are known to have generated an ocean-wide tsunami, principally the Lisbon event.

Another possible tsunami origin in the Atlantic ocean is the eventual collapse of volcanoes' flanks, like in the Canary Islands [11]. This could generate massive waves propagating towards the coasts despite the important dispersion phenomenon for such landslide's waves [12, 13].

The biggest event is represented by the 1st of November 1755 tsunami induced by a Mw=8.5/9.0 earthquake, commonly known as "Lisbon tsunami". In fact the earthquake was strongly felt in the Portuguese capital, Lisbon, where a lot of casualties and destructions have been reported. About 60 thousand people died during this catastrophic event [14]. Casualties and/or damages have been reported along the entire coast of Cadiz Gulf from Morocco [15] to Portugal, Spain, and even to England [16-18] (at mean 900 deaths due only to the tsunami in Lisbon according to [19]). The waves crossed the Atlantic Ocean, impacting Madeira and Azores

*Address correspondence to this author at the Ecole Normale Supérieure, Laboratoire de Géologie, UMR 8538, 24, rue Lhomond, bur. 359, 3ème étage, 75231 Paris CEDEX 5, France; E-mail: jeanrog@hotmail.fr

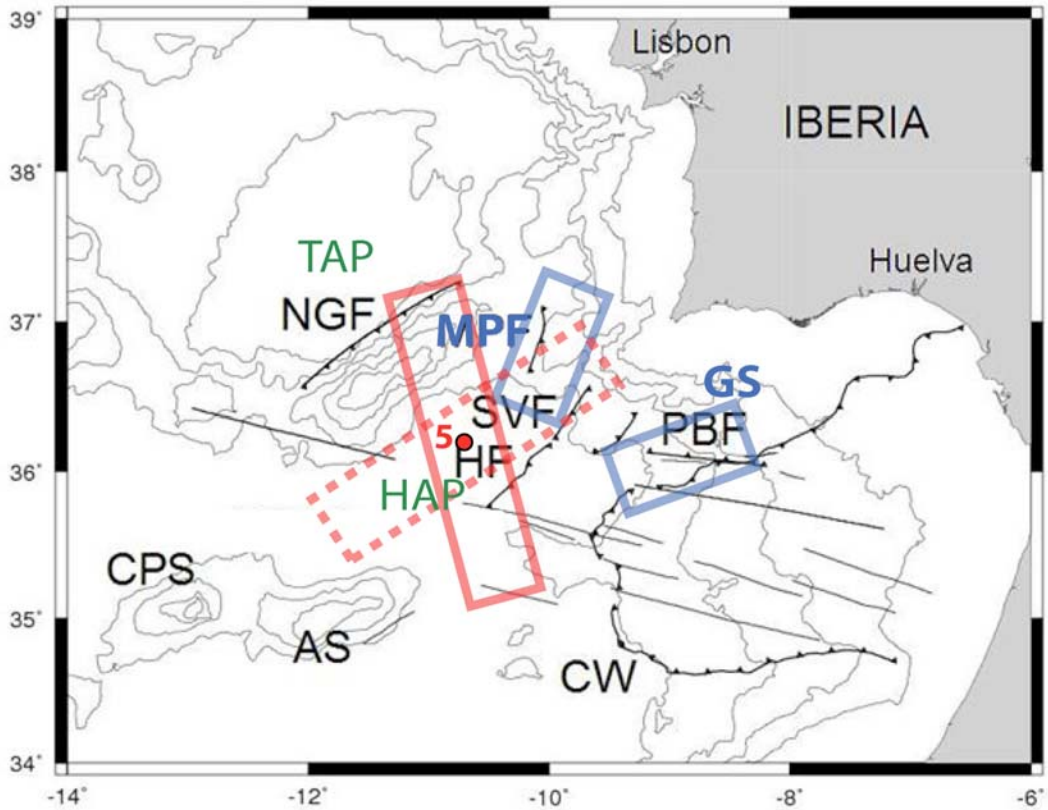

Fig. (1). Location of the tested sources associated to known faults over bathymetric map: [36]'s source n°5 in red solid rectangle and in dashed red for the strike variation of 57°; [42]'s combined source in blue rectangles. *CPS – Coral Patch seamount, AS – Ampere seamount; CW – Cadiz Wedge [40]; NGF - North Gorringe Fault; MPF - Marques de Pombal fault; HF- Horseshoe Fault; SVF - Sao Vicente fault; PBF – Portimao Bank Fault; TAP – Tagus Abyssal Plain; HAP – Horseshoe Abyssal Plain, adapted from* [3].

Archipelagos [20], and were reported possibly as far as Newfoundland coasts [21] and in the West Indies [21-26]. Further analysis of historical documents [27], geological investigations [28] and numerical modelling using backward ray tracing [29, 30] allowed to locate this submarine earthquake southwest of Cape St Vincent, South Portugal [31, 32]. In the last decade a significant effort was made in order to identify possible tsunamigenic sources in the area but until now the source of the 1755 event is still a matter of debate.

Different hypotheses have been proposed associated with different sources especially since the 28th February 1969 Horseshoe Abyssal Plain earthquake [33, 34]. Actually, one of the main problems is that none of these sources can be associated with tectonic structures (presented on Fig. **1**) long enough to account for a Mw 8.5 earthquake. Thus these are not able to explain the important wave arrival and run-up of several meters in different places all along the Atlantic shores and especially in the Caribbean area (Saba, Antigua, Dominica, Guadeloupe, Martinique, ...) mentioned in some historical reports [22-26] and field investigations by [35] as shown by [36]. In Guadeloupe, [35] indicate that the church in Ste Anne (located on Fig. **3**) was hit by the tsunami of 1755. An historical description of the phenomenon in Guadeloupe Island has been collected by [37]: " *Only, on November 1st, a very curious fact occurred and arrived to us by the tradition. On several points of the coast, there was a considerable withdrawal of the sea. At Saint-Anne, it withdrew up to the line of the cayes*[1] *which wrap the natural harbour, by leaving only two passages, and coming back with violence, invaded the earth. In the village, then considerable, of this municipality, the waves came and broke against the porch of the church. This curious phenomenon occurred throughout the Antilles, and it is so described in Ephemerides, noted day by day by an inhabitant of Sainte-Marie's parish (Martinique)*." (this text has been translated from the French original version [37]).

The line of the cayes corresponds to the coral reef barrier that enclosed Sainte-Anne's Bay. It is located about 600 m from the shoreline at its maximum distance. The maximum water depth in the so-formed lagoon is about 3 m. It reaches 6 m depth in the two mentioned passages in [37].

Recent field work, including topography measurements from the shoreline up to the aforementioned church (Fig. **5**) located it at a distance of 220 m in land, with a minimum elevation of the bottom of the church's main door of 3,2 m (Titov, 2008, pers. comm.). We consider that the shape of the bay and the elevation of the church with regard to the sea level 250 years ago have probably not changed significantly since 1755.

Two hypotheses could be proposed in order to explain that none of the proposed sources were able to generate important wave heights in the Antilles: the first concerns the

[1] Caye : French word signifying small rocky islet often composed by sand and/or coral

Table 1. The Fault Parameters from Source n°5 (a) from [36], and Marques de Pombal (MPTF) – Guadalquivir Segement (GS) Combined Source (b) from [42]

Source		Lon(°)	Lat(°)	Depth of Centre of Fault Plane	Average Slip (m)	Strile(°)	Dip (°)	Rake/slip Angle (°)	Length (km)	Width (km)	Rigidity (N.m²)
a) Barkanetal (2008)		-10.753	36.042	30.7	13.1	345	40	90	200	80	45.10
b) Baptista et al (2003)	GS	-8.7	36.1	20.5	20	250	45	90	105	55	30.10
	MPTF	-10	36.8	20.5	20	21.7	24	90	96	55	30.10

fact that trans-oceanic dispersion phenomenon could play a role in such far-field propagation of earthquake generated tsunamis [38] but much less than in the case of landslide generated tsunamis [39], if propagation numerical models take into account this dispersion. The second and more convincing hypothesis is based on the lack of high resolution data used in modellings when approaching the coasts. Thus, these data reproduce more accurately the underwater structures and the shape of the coasts, and allow to properly account for the non linear coastal amplification of tsunamis.

The objective of this study is not to discuss the previously proposed seismic sources [28, 32, 36, 40-42]; the goal is to investigate wave amplification phenomena in the Guadeloupe shield using high resolution datasets, underlining the probable important character of resonance phenomenon in the West Indies in harbours and in water bodies formed by coral reef barriers [43, 44]. We focus our study on Guadeloupe Island and more particularly on the previously mentioned bay of Ste Anne.

2. BATHYMETRIC GRIDS AND NUMERICAL MODELLING OF TSUNAMI GENERATION AND PROPAGATION.

The numerical model used in this study to compute tsunami generation and propagation associated with earthquake has been used for years in order to study tsunami hazard for various exposed regions, from French Polynesia [45] to the Mediterranean Sea [46-49].

The initial deformation calculus is based on elastic dislocation computed through Okada's formula [50]. Our method considers that the sea-bottom deformation is transmitted without losses to the entire water column, and solves the hydrodynamical equations of continuity (1) and momentum (2). Non linear terms are taken into account, and the resolution is carried out using a Crank Nicolson finite difference method centred in time and using an upwind scheme in space.

$$\frac{\partial(\eta + h)}{\partial t} + \nabla.[v(\eta + h)] = 0 \qquad (1)$$

$$\frac{\partial v}{\partial t} + (v.\nabla).v = -g\nabla\eta \qquad (2)$$

η corresponds to the water elevation; h to the water depth; v to the horizontal velocity vector; g to the gravity acceleration.

The wave propagation is calculated from the epicenter area in the Cadiz Gulf (Southern Portugal and Spain to the East) through the Atlantic Ocean (Fig. **2**) on 5 levels of imbricated grids of increasing resolution as approaching Guadeloupe Archipelago with a special focus on Ste Anne's Bay. The larger grid (0), corresponding to the geographical coordinates of Fig. (**2**), is built from GEBCO World Bathymetric Grid 1' [51] and is just a resampling of this grid at a space step of 5'. The grid resolution increases close to the studied site i.e. when the water depth h decreases along with the tsunami propagation celerity $c = \sqrt{gh}$ that depends only on h in shallow water non dispersive assumption. The time step used to solve the equations decreases when the grid step decreases, and respects for each grid level the CFL (Courant-Friedrichs-Lewy) criterion to ensure the numerical stability.

The grid (1) is a focus on Guadeloupe Archipelago with a resolution of 1'. It has been obtained by a combination of GEBCO 1' data and high resolution multi-beam, resampled bathymetric data from the French Hydrographic Service (SHOM). This grid has been included only for numerical stability reasons. The grid (2) has nearly the same geographical coordinates of grid (1) (Fig. **3**), including the whole Guadeloupe Archipelago with a spatial resolution of 500 m. The data used are the same as for grid (1).

The grid (3) represents a focus on Point-à-Pitre's Bay with a spatial resolution of 150 m and has been computed using re-sampled SHOM dataset only.

High resolution grid of Sainte-Anne's Bay, which is set up for the final grid level, is obtained from digitized, georeferenced and interpolated nautical bathymetric charts and multi-beam bathymetric data from the French Hydrographic Service (SHOM). This grid (4) has a resolution of 40 m and it is able to reproduce the coral reef barrier partially closing the bay and the shallow bathymetric features which could have a significant influence on wave trapping and amplification, potentially associated with resonance phenomenon.

Another grid of Ste Anne's Bay with a resolution of 10 m was computed in order to test these resonance effects. This grid (5) has not been included in the propagation calculations.

3. TESTED SOURCES

Several sources have been tested from the literature [28, 32, 36, 41, 42], and we decided to present the two sources that best fit the West Indies historical observations.

The first one is the source (n°5) with optimized parameters from [36]. In spite of the fact that this source is not very well constrained through morphological analysis (Fig. **1**) this is the first simulation that shows significant amplification in the West Indies, on a low resolution grid (ETOPO2, 2' resolution).

The second tested source concerns the Marques de Pombal – Guadalquivir combined source from [42]. Despite the fact that the proposed coseismic slip might to be too large regarding the geodynamical conditions (especially the plates convergence rate), this source has the advantage to be based on proved geological submarine features [28] visible on Fig. (**1**).

Concerning the first case, the used parameters are issued by [36]. They are presented in Table **1** and are consistent with a Mw=8.5±0.3 earthquake commonly accepted for this event [52] and associated with a seismic moment $5 < Mo < 10.10^{21}$ N.m. As the shear modulus μ indicated by [36] seems to be too large for this region (they use $\mu \sim 60.10^{9}$ N.m² associated with a seismic moment (Mo) of $1.26\ 10^{22}$ N.m), we decided to test $\mu = 30.10^{9}$ N.m²,value commonly used in this region, and $\mu = 45.10^{9}$ N.m², more currently used in compression zone in oceanic lithosphere context. This rigidity parameter (or shear modulus) is estimated from previous studies of [53] and [54], in accordance with relationships between all faults parameters presented by [55] and relevant with a compressionnal mechanism in this area. The lowest value gives a Mw=8.5 earthquake and the second one a Mw=8.6 earthquake. Then we test a variation of the strike angle for this source, all other parameters remaining equal; the two different azimuths are presented on Fig. (**1**).

The second tested source has been proposed by [28] and [42] as previously mentioned and corresponds to a Mw=8.5 earthquake (Mo=$6.63\ 10^{21}$ N.m). It is a combination of two fault segments located offshore Southern Portugal and Iberia: the Marques de Pombal Thrust Fault (MPTF) and the Guadalquivir Segment (GS). They are located on Fig. (**1**) and their parameters are described in Table **1**.

4. RESULTS OF MODELLING

The presented results are obtained after 9 hours of tsunami propagation in the Atlantic Ocean. The first wave reached the easternmost island of Guadeloupe Archipelago circa 7 hours (propagation) after the earthquake (synthetic gage 6 on Fig. **6**) which is in agreement with tsunami travel time indicated in historical reports presented in [56] or in [57].

The results of calculations with two different values for the shear modulus in the case of [36]'s source indicate no differences of far-field wave amplification between these two cases, all other parameter remaining equal. Thus we do not discuss more about the choice of this parameter in this study.

Fig. (**2a**) represents the maximum wave heights obtained on grid (0) (North-Atlantic Ocean) after 9 hours of tsunami propagation using the source n°5 from [36]. Maximum wave heights reached nearly 5 m above the rupture area. The results show that the tsunami energy is not radiated uniformly but seems to follow two major wave paths: the first one towards the Azores Islands and Northern America, especially Newfoundland. The second one oriented toward Southern America (French Guyana, Surinam) and the West Indies. [58] and [59] show that these paths are due firstly to the tsunami initial directivity associated to the fault azimuth and then to the refraction of tsunami waves in shallow regions as

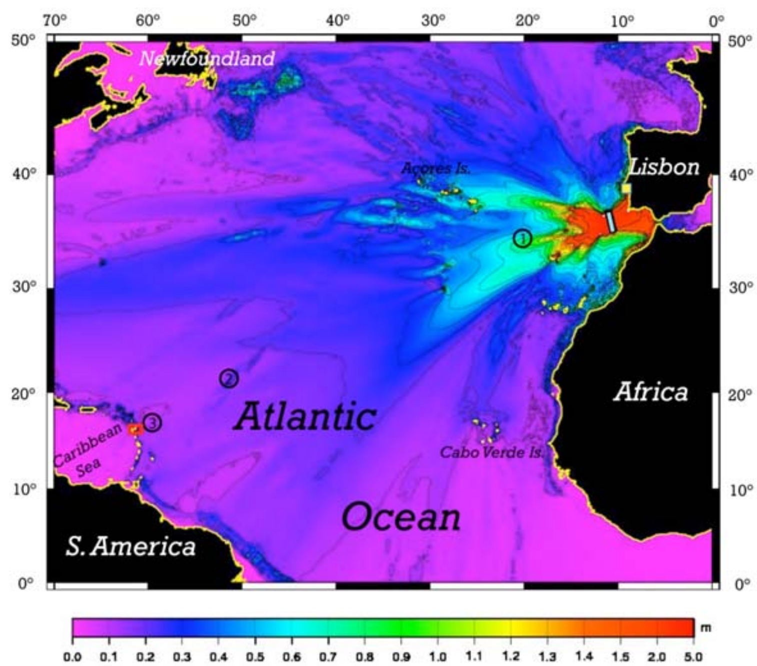

Fig. (2a). Maximum wave heights cumulated on 9 hours after the seismic rupture southwestern Lisbon and calculated on a 5' resolution grid (grid 0). The black and blue rectangle indicates [36]'s source n°5 and the red rectangle shows the location of grid (2). Numbers indicate synthetic tide gages location.

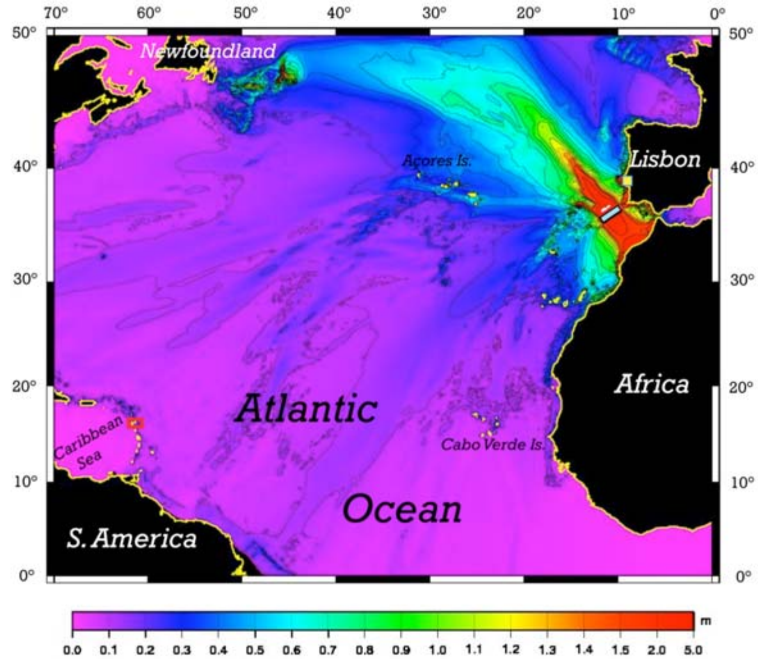

Fig. (2b). Maximum wave heights cumulated on 9 hours after the seismic rupture southwestern Lisbon and calculated on a 5' resolution grid (grid 0). The black and blue rectangle indicates [36]'s source n°5 with strike 57° and the red rectangle shows the location of grid (2).

mid-ocean ridges leading to a focusing and defocusing of these waves. Mid-ocean ridges and continental shelves can act as topographic waveguides which is known as trapping effect [58].

Fig. (**2b**) displays the maximum wave heights obtained on grid (0) (North-Atlantic Ocean) after 9 hours of tsunami propagation using the source n°5 from [36] with a modified strike angle of 57° instead of 345° for the previous test. This angle corresponds to the estimated strike of the Gorringe Bank (NGF in Fig. **1**). In this configuration, the major part of wave energy is radiated in a NW-SE direction toward Greenland and Newfoundland to the North-West and Morocco to the South-East.

Fig. (**2c**) represents the maximum wave heights obtained on grid (0) (North-Atlantic Ocean) after 9 hours of tsunami propagation using the combined source from [42]. The wave

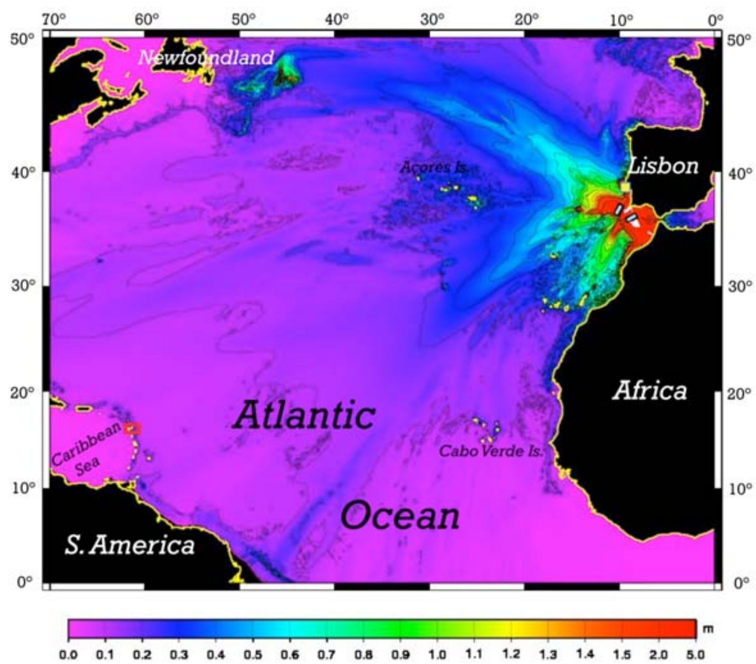

Fig. (2c). Maximum wave heights cumulated on 9 hours after the seismic rupture southwestern Lisbon and calculated on a 5' resolution grid (grid 0). The black and blue rectangles indicates [42]'s composed source.

energy is radiated mostly toward Greenland and Newfoundland to the North-West, Morocco and Canaries Islands to the South and toward Southern America to the South-West.

Fig. (**3a-3b-3c**) shows the maximum wave heights in Guadeloupe Archipelago always after 9 hours of propagation onto grid (2) in each of the 3 previously presented cases. The imbrication time between each grid has been cautiously estimated in order to be sure to catch the first sea surface deformation in the underneath grid. It reveals that wave amplification is not constantly distributed along the coastlines of the different islands. Only several locations are subject to wave heights of more than 0.5 m until 2.2 m. These locations are the same for each tested sources in the framework of that study with more or less amplifications, highlighting the local amplification processes only related to local bathymetry and coast locations. It is interesting to notice that these are the same places considering wind-generated waves amplification; for example: Sainte-Anne, Saint-François, Le Moule, Anse-Bertrand (located on Fig. **3a**, **3b** and **3c**) for Grande-Terre are good places for wave amplification due to local

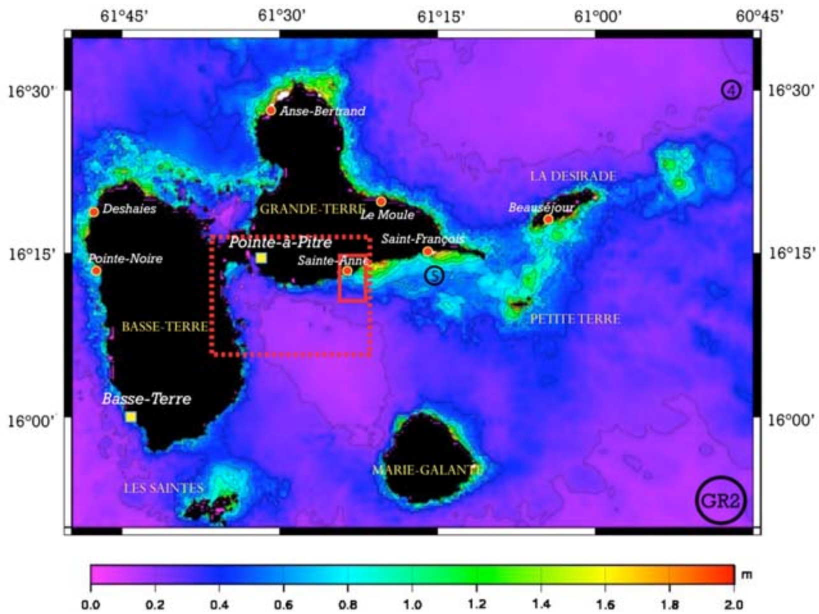

Fig. (3a). Maximum wave heights on Guadeloupe Archipelago (grid 2) using [36]'s source n°5. The red dashed rectangle indicates the location of grid (3) (150 m) and the red solid rectangle the location of grid (4) (40 m resolution) on Ste Anne's Bay (Fig. 4). Numbers indicate synthetic tide gages location.

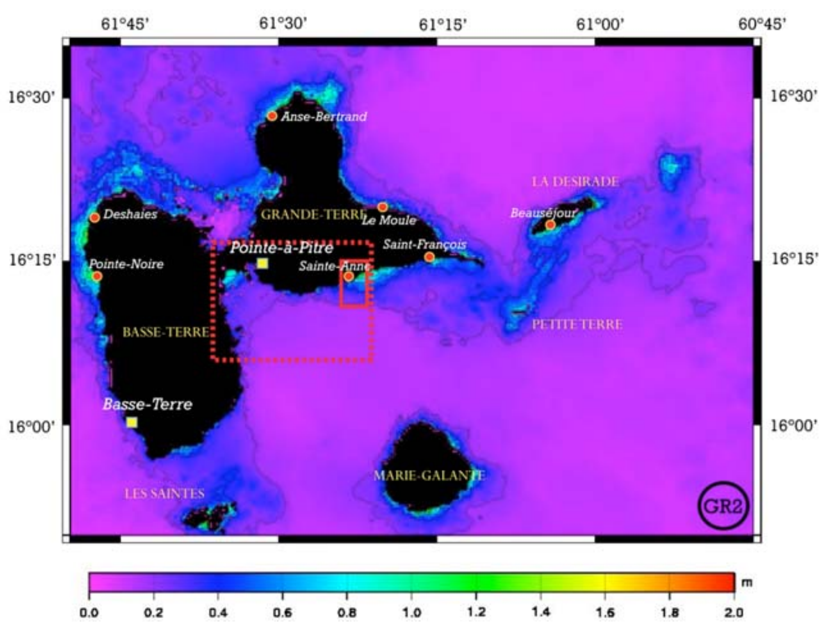

Fig. (3b). Maximum wave heights on Guadeloupe Archipelago (grid 2) using [36]'s source n°5 with strike 57°

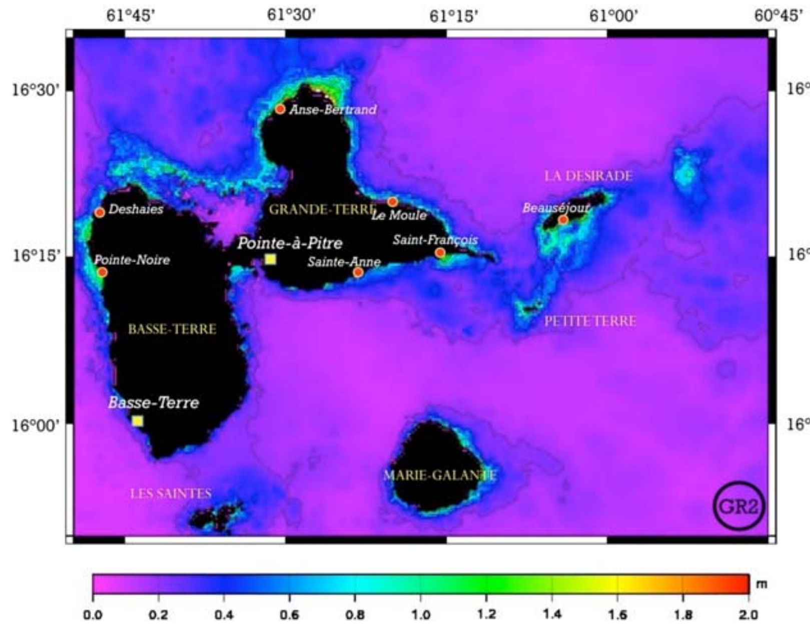

Fig. (3c). Maximum wave heights on Guadeloupe Archipelago (grid 2) using [42]'s source.

bathymetry with very low slope. A focus on these special areas shows that the characteristic wavelengths are approximately the same order of those of the bays where there is important wave amplification.

Other locations are highlighted on the other islands of the archipelago as on La Désirade or Les Saintes. There are some wave amplification on Petite-Terre Islands: despite these places are uninhabited, the fact that it is a game reserve, frequented daily by tens of tourists, forces us to consider these islands in hazard studies, mainly due to their poor elevation (peak at 8 m).

Fig. (**4**) shows a focus on maximum wave heights calculated in Point-à-Pitre's Bay and nearby areas (grid 3). It allows to see if wave amplifications are located near populated areas [60] as Le Gosier, Saint-Anne, Goyave, etc. Thus, there are some wave heights of more than 1 m in Saint-Anne's Bay and in the lagoon between Le Gosier and its little island called "îlet du Gosier", places which are highly

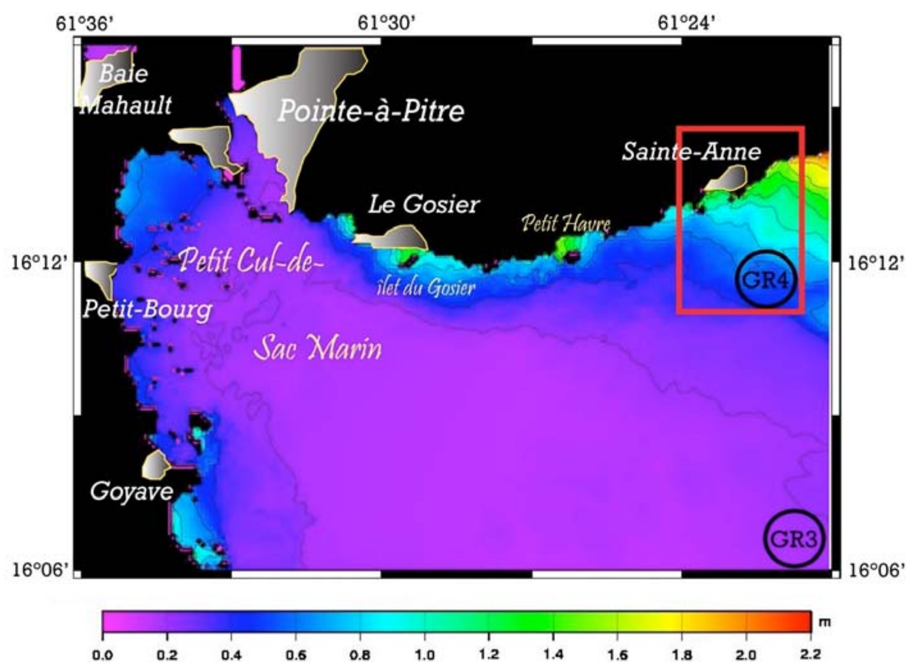

Fig. (4). Maximum wave heights on grid (3) using [36]'s source n°5. Populated areas are reported in grey; the red rectangle indicates location of grid (4).

frequented because of their famous white sand's beaches. There are significant heights in the "Petit Havre" lagoon between Le Gosier and Sainte-Anne, located outside urbanized areas but as commonly frequented by tourists, divers and surfers.

Fig. (**5**) shows a zoom on maximum wave heights calculated in Sainte-Anne's Bay (Grande-Terre) and nearby areas (grid 4). The calculation results cumulated on 9 hours have been associated with a satellite view [61] in order to have an idea of the potentially endangered coastal areas in the case of such a scenario. The maximum wave height recorded in this bay are usually not greater than 1.2 m. Belley's Bay, next bay to the East, shows wave heights reaching more than 2 m.

5. DISCUSSION

Fig. (**6**) shows the tsunami signal recorded on several synthetic tide gages located on its way from the Iberian Peninsula to the bay of Sainte-Anne, Guadeloupe. Firstly we can see that the signal (especially the first tsunami wavelength) is attenuated when crossing the Atlantic Ocean from tide gage 1, located near the rupture area, to gage 2 and then gage 3, near the Caribbean Sea, in what concerns grid (0) (synthetic tide gages 1, 2 and 3 are located on Fig. **2a**). As expected, the signal is the same between gage 3 and gage 4 (located on Fig. **3a**) because they are located in the same area on two different grids. Then it is interesting to mention an amplification of the signal as approaching the coastline (shoaling effect) and the progressive appearance of what seems to be a long-period oscillation with a period of about 15 minutes, about 30 minutes after the first arrival. This could be attributed to a resonance phenomenon due to the interaction of the long waves with the Guadeloupian shelf as shown by [62].

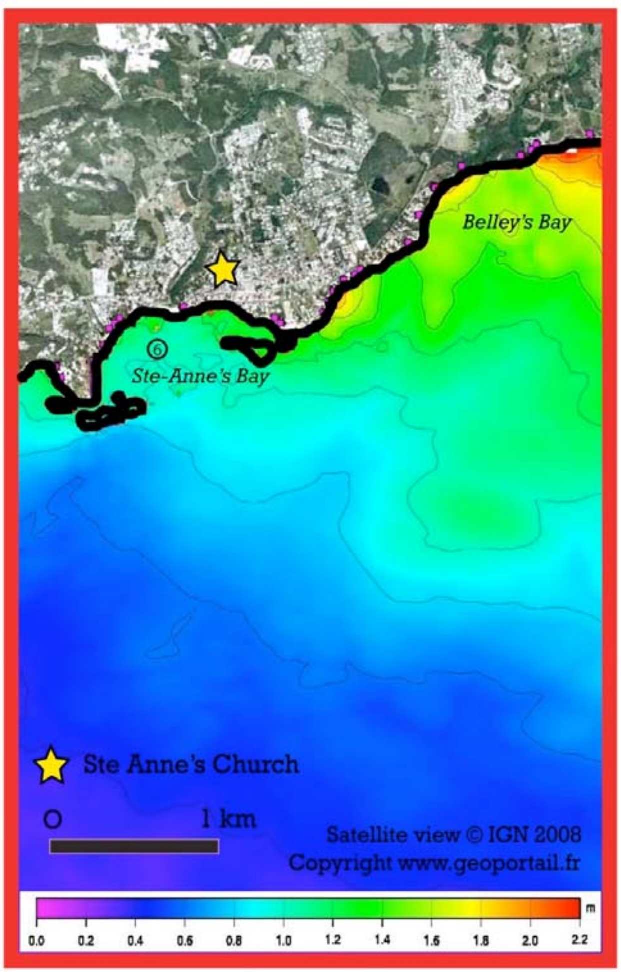

Fig. (5). Maximum wave heights on grid (4) using [36]'s source n°5. A satellite view is superimposed on it. The number in Saint-Anne's Bay indicates the synthetic tide gage (6) location.

According to the fact that every water body (including man-made harbors or bays) has a natural oscillation mode with eigenperiod depending on physical characteristics of the water body [63] i.e. its geometry and depth [64, 65], we calculate the resonance of the Saint-Anne's Bay using a method inspired from [66]. This study proposes the use of spectral analysis with an FFT algorithm from the evolution of an arbitrary initial surface (we use a Gaussian surface) at some gage points. One of the spectrum that we obtained is represented on Fig. (**7**). We can see several resonance periods which correspond to the natural eigenperiods of the bay. The largest is approximately at 890 seconds, while the others at 400, 305, 213, … seconds.

When we assume that the considered bay can be assimilated to an elongated channel of 1300 m length (longitudinal cross section) and 4 m depth, e.g. with a parabolic shape, we can use a simple analytic model [67] which predicts that the highest period is $T = \frac{2l}{\sqrt{gh}}$ (internal resonance of the bay). This corresponds in our case, to a period of 400 seconds. The first period, very large and also dissipative (890 s), can be explained with the non-closed structure of the bay. The period analysis of the synthetic signal recorded on gage 1 (grid 0), i.e. near the source, shows that in both cases of tested source [36, 42], we can observed period peaks at the resonance periods of the bay (Fig. **8A** and **8B**). These peaks are observed on the period spectrum of the signal of the synthetic tide gage located within the bay (Fig. **9A** and **9B**). A focus on the small periods range (< 500 s) shows that the signal coming from [42]'s source is more enclined to react at the resonance period of the bay (Fig. **9B**) than the one generated by [36]'s source.

CONCLUSION

Despite the lack of reported information concerning the tsunami arrival in 1755 in Guadeloupe Archipelago, numerical modelling indicates that these islands are not protected from an ocean-wide tsunami generated by a 1755-like earthquake offshore the Iberian Peninsula even if the rupture mechanism is not favourable. Indeed the fault's strike angle of these sources does not allow for major wave propagation towards the West Indies, as shown with the Gorringe Bank's strike angle attributed to [36]'s source. However, the sensitivity study of the strike of [36]'s source shows that the strike 345° has an important role on wave coastal amplification.

Thus, this study clearly shows that a seismic source [36, 42] located in the eastern part of North Atlantic Ocean is

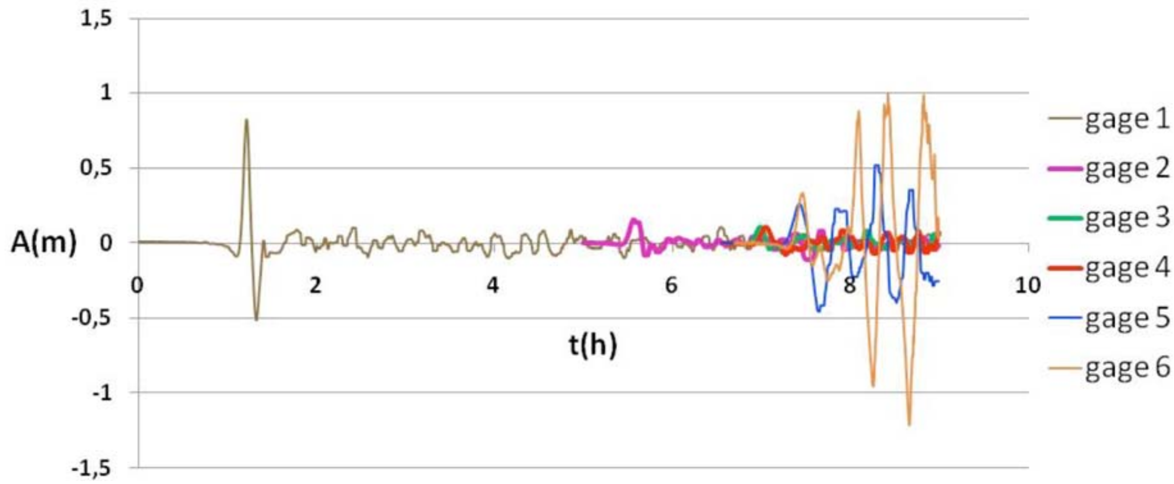

Fig. (6). Signal recorded on synthetic tide gages located on three different grids from the source area to the bay of Sainte-Anne (Guadeloupe). The position of each tide gages are reported on Fig. 2, 3 and 5.

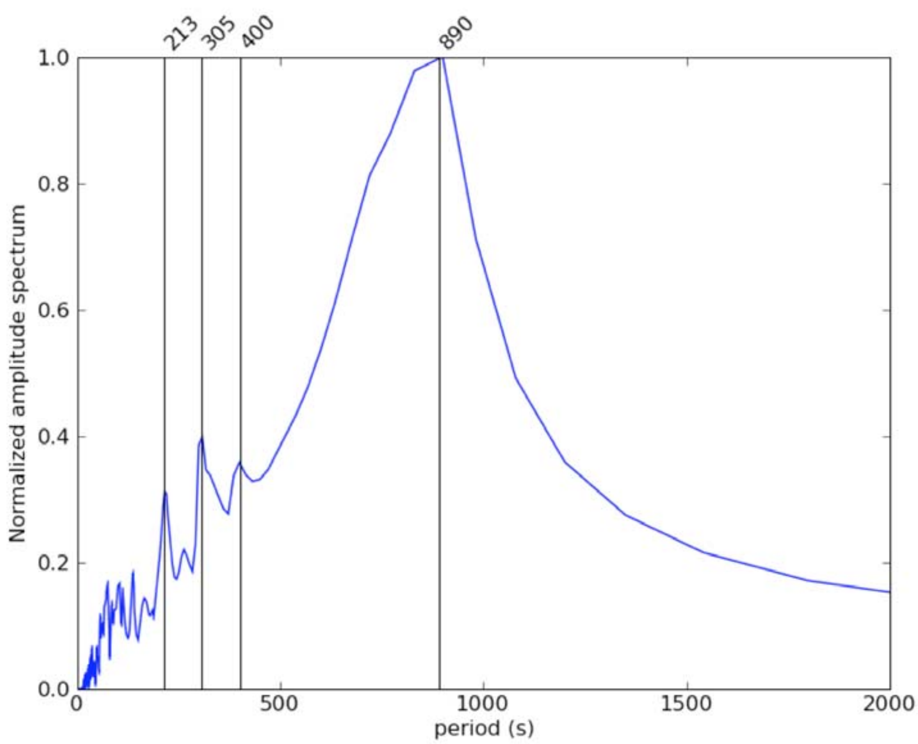

Fig. (7). Normalized amplitude spectrum of the bay of Saint-Anne.

able to produce important wave heights of more than 1 m in the Guadeloupian Archipelago, especially in some well-shaped bays or lagoon, whatever the rupture fault strike angle. But, the tested source from [36], with a well-oriented strike, leads to a major energy path towards the West Indies, producing wave heights of more than 2 m. This corresponds to wave amplification of a factor 20 in the case of [36]'s source. In the same way, [42]'s source leads to a wave amplification from 0.1 m offshore the island to more than 1 m in some particular coastal locations i.e. a factor 10. These observations are in good agreement with [68].

The second important thing that this study highlights, is that the Guadeloupian shelf seems to react to long-wave arrivals, leading to a low-frequency oscillation. The resonance study of such places allows to determine which particular range of period is able to amplify when entering these water bodies.

In summary, we conclude that it is not necessary to have a source radiating maximum wave energy towards the Caribbean Islands to produce significant waves in this area. This study does not allow for a distinction between proposed source mechanisms for the 1755 event, i.e. which source

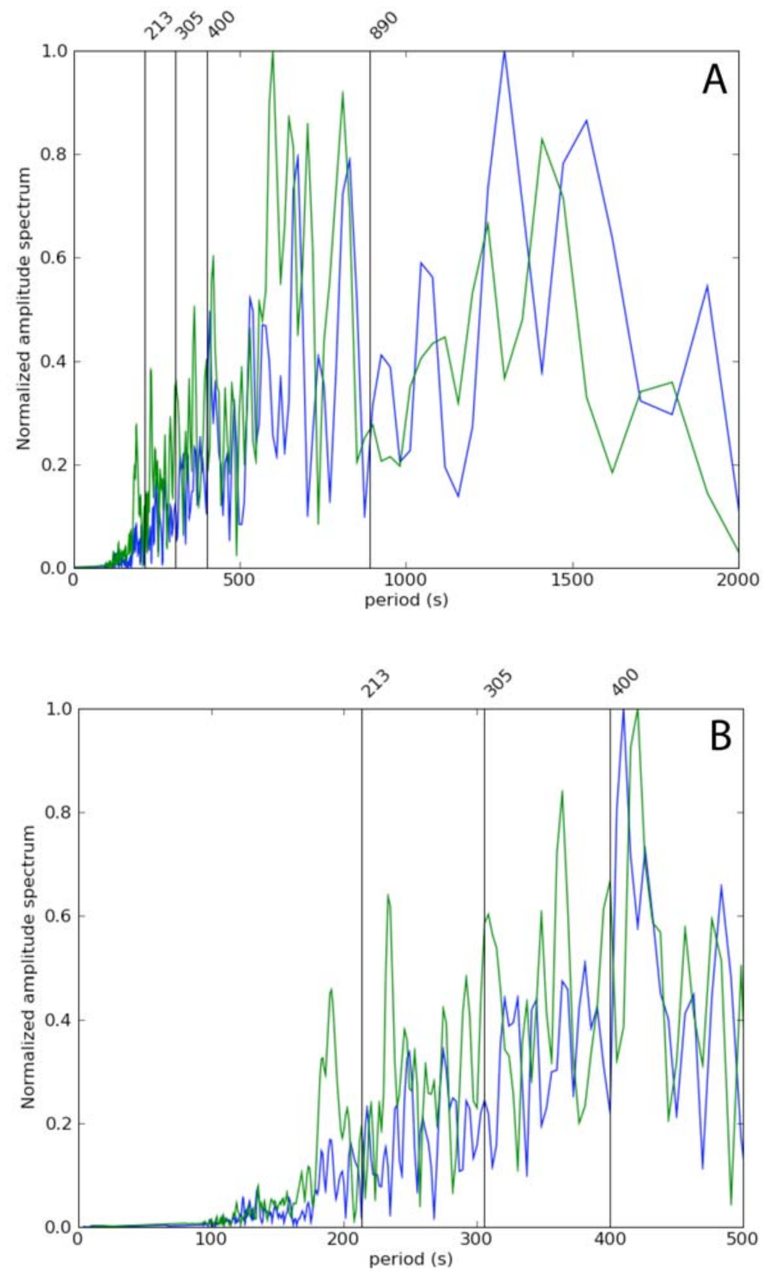

Fig. (8). Normalized amplitude spectrum of the synthetic signal computed near the source (grid 0, gage 1) in both tested cases [36, 42]; **A**) the full period spectrum, **B**) focus on low period modes. [36]'s source is represented in blue and [42]'s source is represented in green.

location and parameters gives the best match between simulations and observations. It clearly shows that different proposed sources for a 1755-like event produce significant amplifications in the Caribbean Islands as reported in historical documentations.

The important increase of coastal population and infrastructures since 1755, especially in the Caribbean Islands due to intensively developing tourism, coupled with the results presented in this study clearly show the importance of the implementation of a tsunami warning system in the Atlantic that can account for tele-tsunamis. Thus other far-field events as the 1761 tsunami should be considered further. All the more as, in such case of far field tsunamis, people do not locally feel the earthquake as a warning sign.

Future work on far-field impact should focus on Martinique Island (French territory), 150 km south to Guadeloupe, and/or other locations on the Western coasts of the Atlantic Ocean, in order to try to correlate November 1755 historical reports and numerical modelling results.

ACKNOWLEDGEMENTS

We would like to thank the SHOM (France) for providing us the high resolution bathymetric dataset for Guadeloupe; Eric Thauvin (CEA-DASE) for is precious help concerning grids making; Prof. Narcisse Zahibo for his invitation to the workshop "Caribbean Waves 1" and his availability for the field survey at Sainte Anne's; Dr Paul Louis Blanc

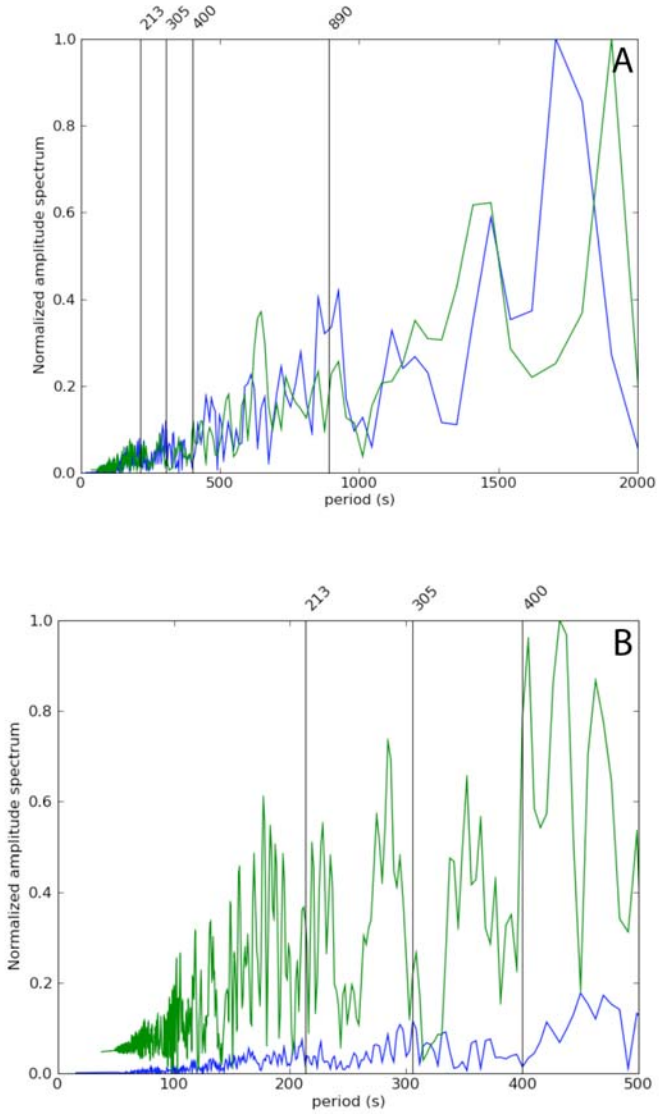

Fig. (9). Normalized amplitude spectrum of the synthetic signal computed in the bay (grid 0, gage 1) in both tested cases [36, 42]; **A**) the full period spectrum, **B**) focus on low period range. [36]'s source is represented in blue and [42]'s source is represented in green. An offset as been introduced between the two signals for a better visibility.

for sending some original reports from Martinique; and Laurence Roger for the translation of historical documents.

We would like to thank the two referees, Carl B. Harbitz and Ahmet C. Yalciner for their constructive comments concerning our manuscript.

This study has been funded by the project MAREMOTI from the French ANR (Agence Nationale de la Recherche), under the contract ANR-08-RISKNAT-05-01c.

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Received: October 15, 2009 Revised: November 05, 2009 Accepted: December 07, 2009