Effect of the 1755 Lisbon tsunami in the French West India

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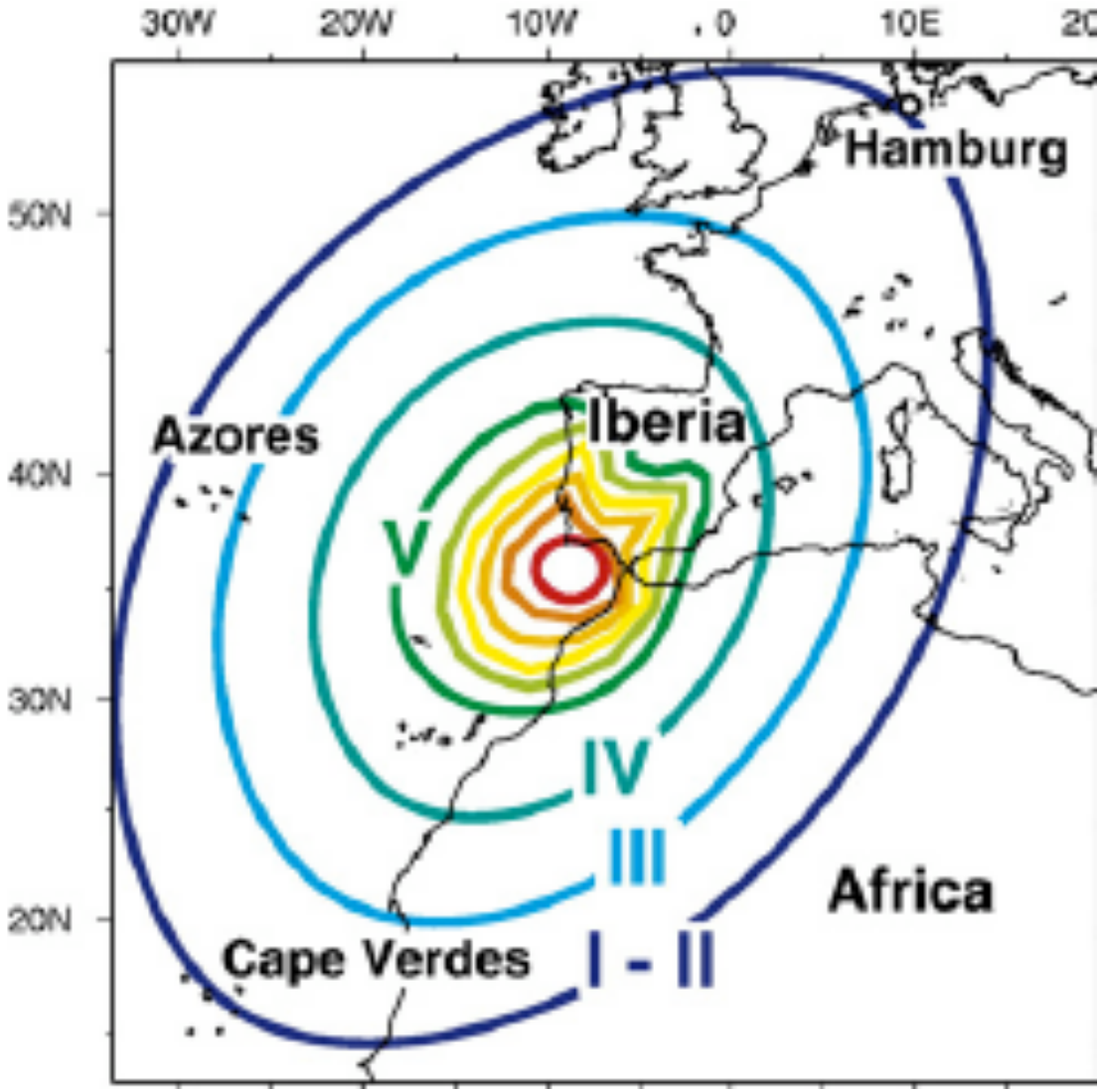
The 1775 Earthquake in Portugal

The Great Lisbon earthquake has the largest documented felt

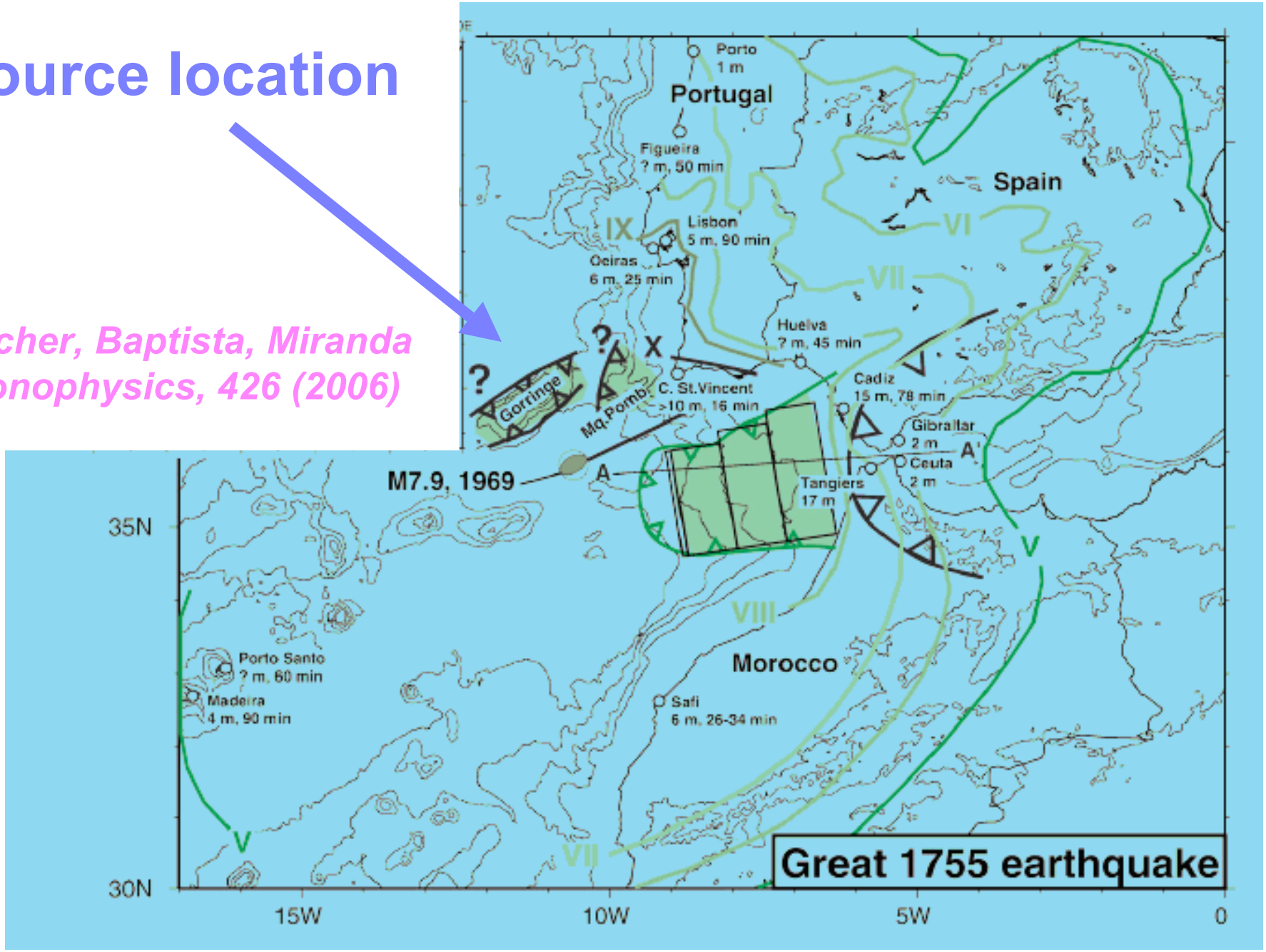


magnitude 8.5 – 9.0

November 1, 1755

Source location

Gutscher, Baptista, Miranda
Tectonophysics, 426 (2006)



Tsunami in Lisbon

The 1775 Tsunami in Europe

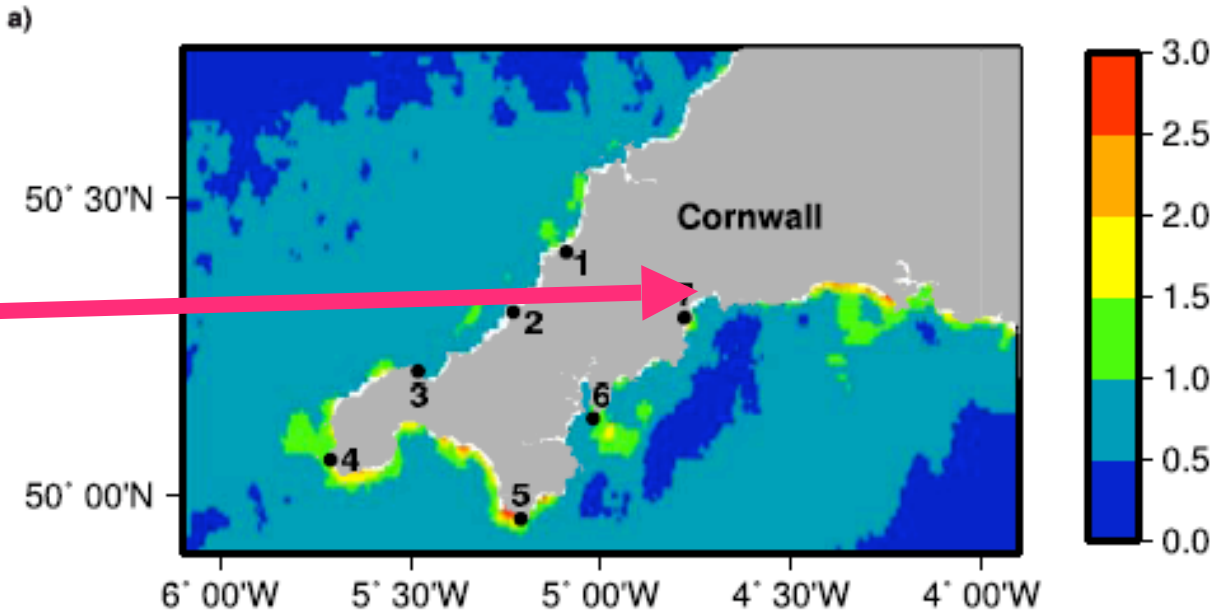
Location	Coordinates	Wave height (m)	Travel time (min) and estimated error
Portuguese west coast			
Porto	8.18° W,41.15° N	1	—
Figueira da Foz	8.88° W,40.14° N	—	45–50
Lisboa (Oeiras)	9.08° W,38.73° N	5	25 (estimated error±10)
Cabo S Vicente	8.99° W,37.00° N	> 10	16 (estimated error±7)
Gulf of Cadiz			
Cadiz	6.30° W,36.05° N	15	78 (estimated error±15)
Huelva	6.93° W,37.25° N	—	45 (estimated error±10)
Ceuta	5.32° W,35.88° N	2	—
Gibraltar	5.35° W,36.15° N	2	—
Madeira Islands			
Madeira	16.88° W,32.63° N	4	90 (estimated error±15)
Porto Santo	16.16° W,33.06° N	—	60 (estimated error±15)
Cornwall (UK)			
Penzance	5.53° W,51.52° N	2	315
Newlyn	15.56° W,50.10° N	—	279
Plymouth	4.15° W,50.31° N	—	390
Morocco			
Safi	9.33° W,32.30° N	—	26–34 (estimated error±20)

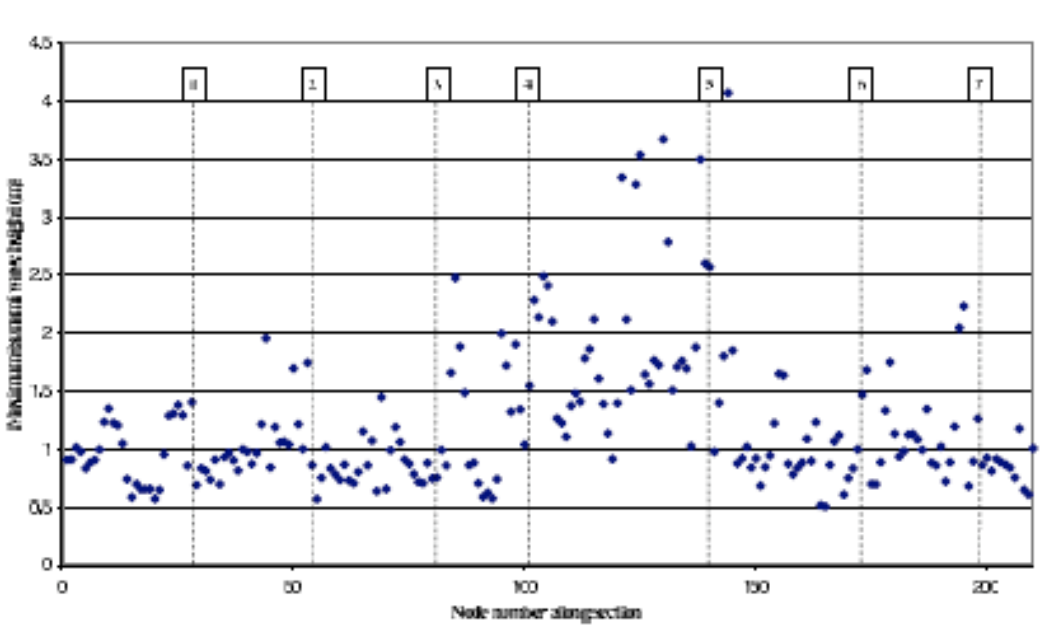
UK coast

3 m observations

Horsburg et al, JGR 113 (2008)

Numerical modeling



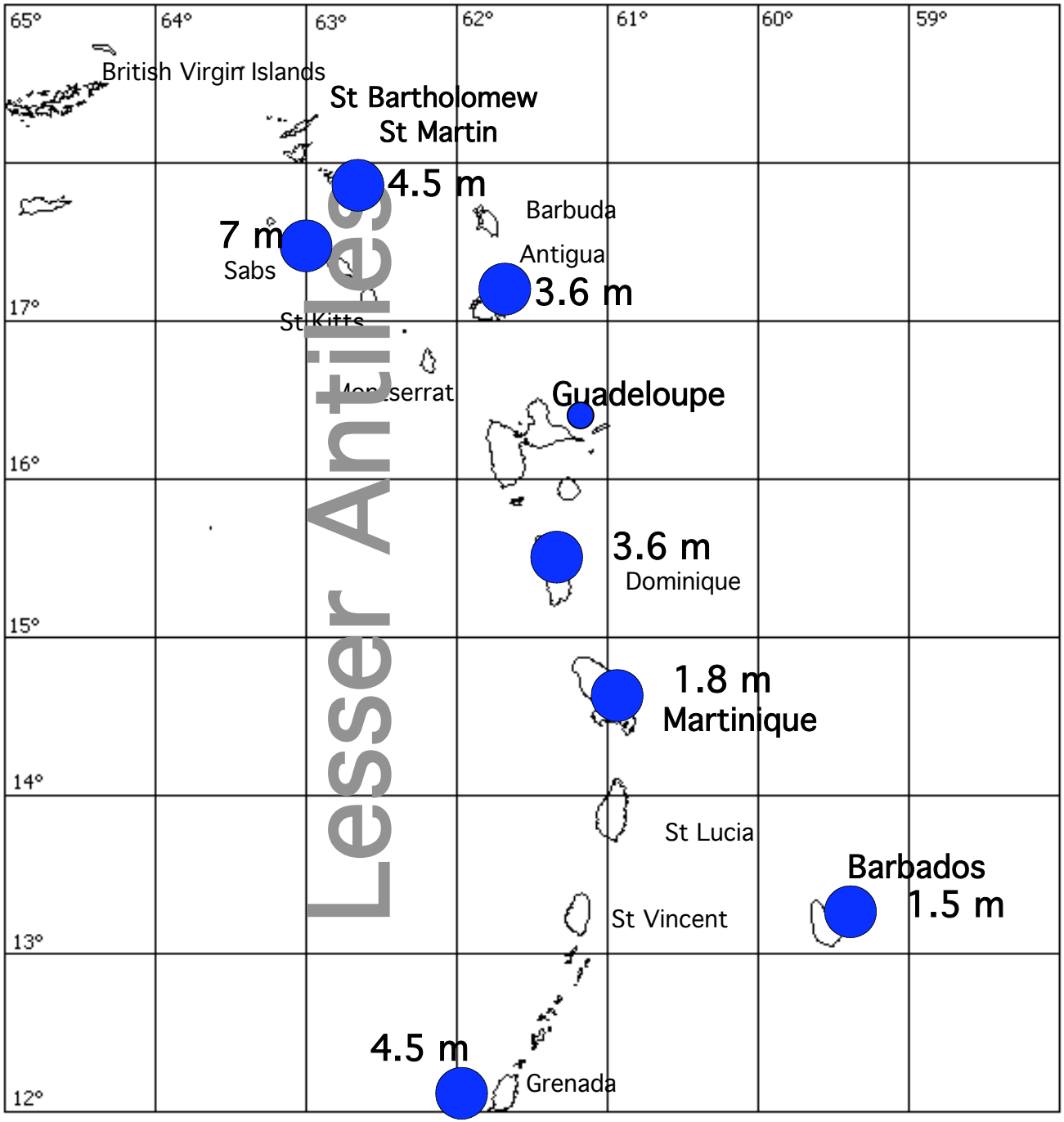


1755 tsunami in Lesser Antilles

*"At **St. Martin**, the **sea retired** so far that a sloop, attached to its anchor in 15 feet [4.6 m] of water, was laid dry on her broadside.*

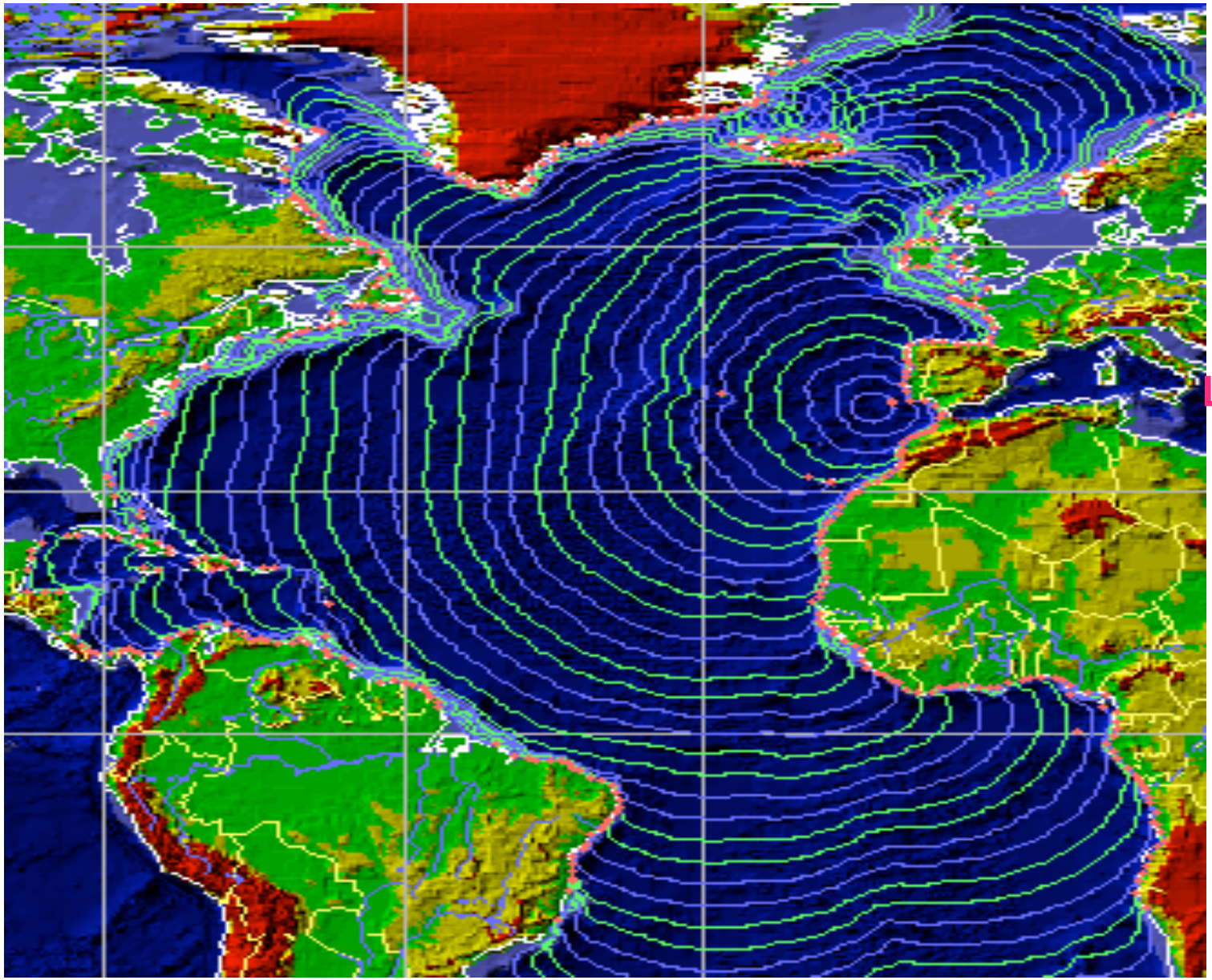
*At **Martinique** and most of the **French Islands**, it overflowed the low land, and returned quickly to its former boundaries. in that **remarkable flux and reflux of the sea**, some places were left dry on approximately a mile*

In the West Indies, this extraordinary motion of the sea was observed 6 hours after the first shock was felt at Lisbon.



1755
tsunami

Tsunami Travel Time (*Gusiakov*)



6-7 hr
to
Lesser Antilles

MODELING THE 1755 LISBON TSUNAMI

Charles L. Mader

Science Tsunami Hazards
19 No. 2 (2001)

TABLE I
CALCULATED DEEP WATER WAVE HEIGHTS
FOR 1755 LISBON TSUNAMI

No	Depth Meters	Location	Maximum Amplitude Meters	Minimum Amplitude Meters
1	953	Off Lisbon	+20.	-20.
2	4747	East of Saba	+2.5	-3.2
3	825	East of Saba	+5.	-4.
4	3446	North of San Juan	+2.	-3.5
5	783	East of Miami	+2.	-3.5
6	2922	East of Washington	+2.	-3.5
7	178	South West of England	+6.	-9.
8	4574	West of Lisbon	+9.	-13.
9	3868	West of Lagos	+7.	-11.
10	3923	West of Gibraltar	+5.	-13.
11	4376	West of Gibraltar	+10.	-13.
12	1717	West of Casablanca	+15.	-15.
13	3314	West of Source	+7.	-8.

SWAN - code

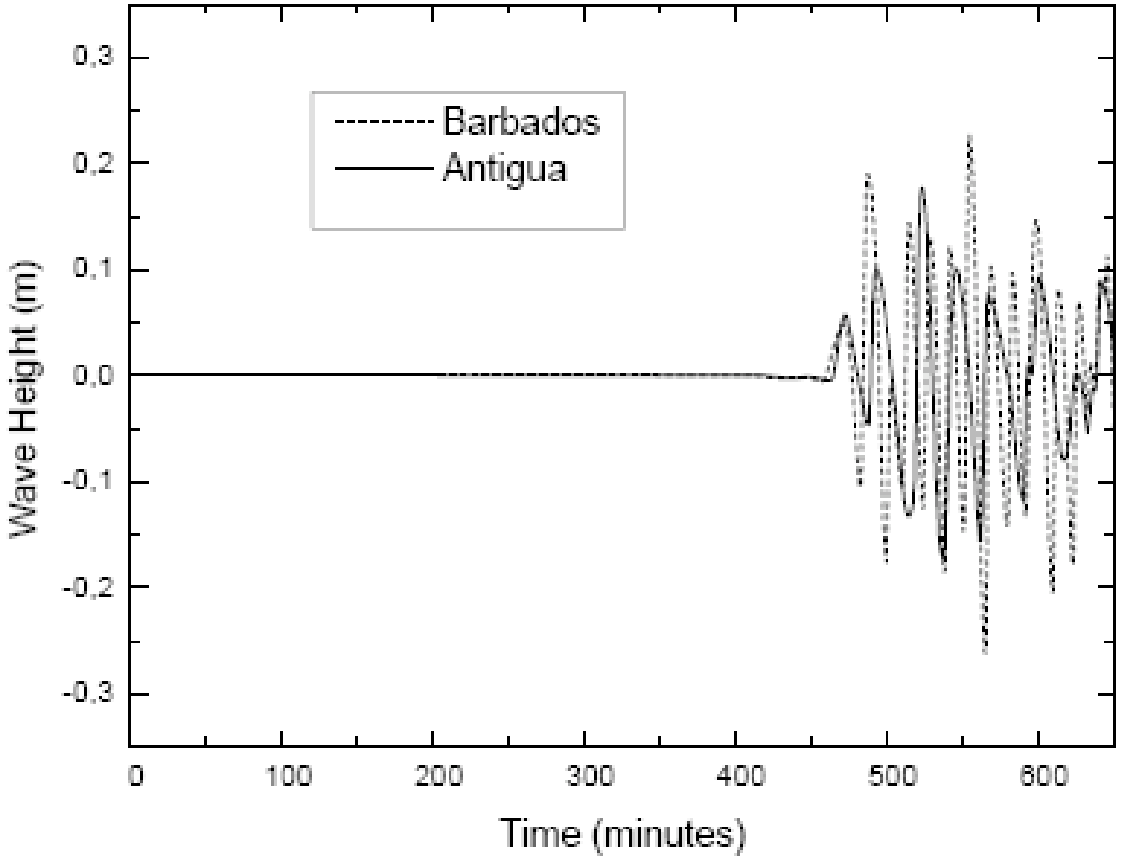
Natural Hazards and Earth System Sciences (2003) 3: 333–340

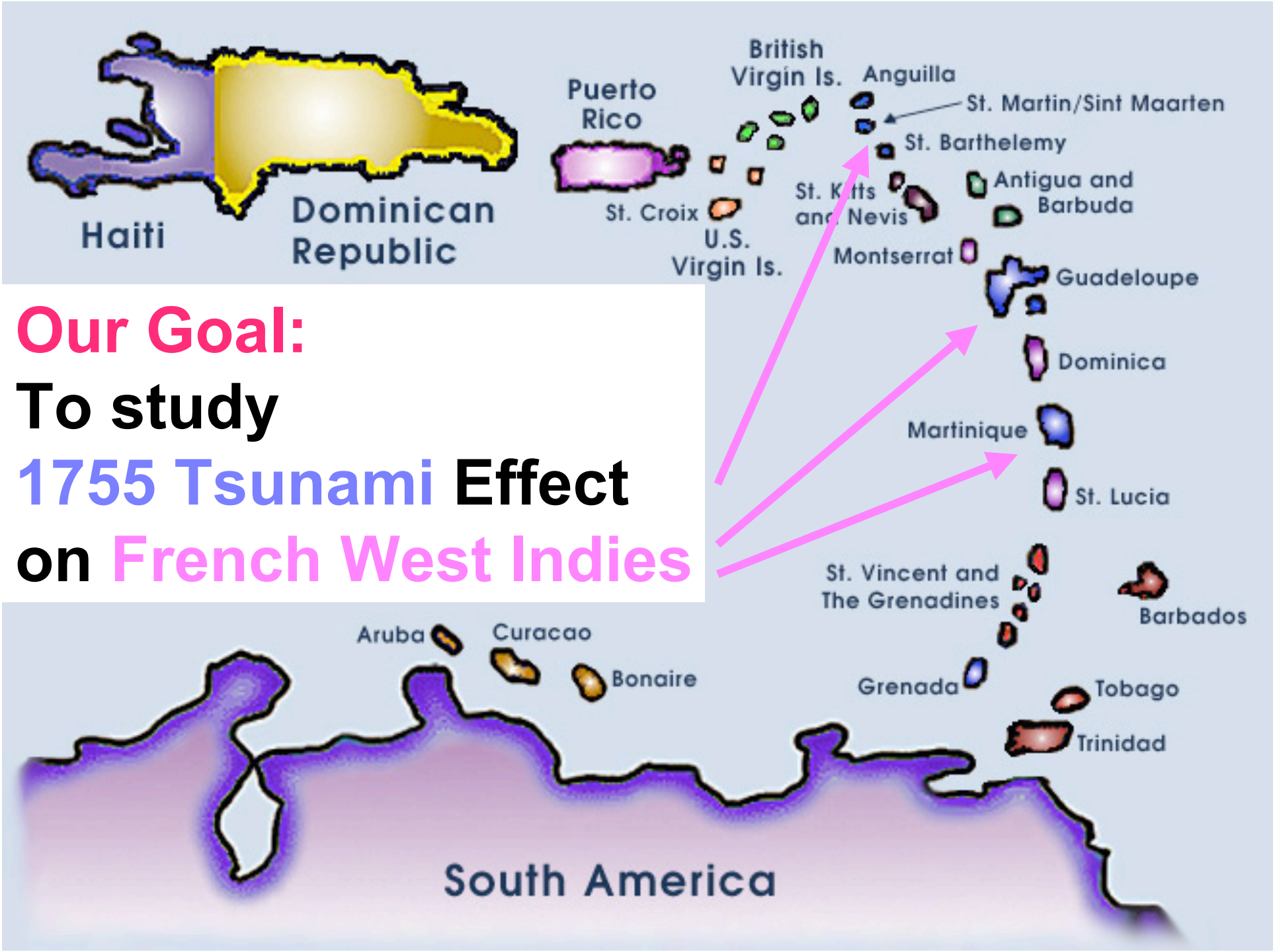
Natural Hazards and Earth System Sciences

New study of the 1755 earthquake source based on multi-channel seismic survey data and tsunami modeling

M. A. Baptista[1, 2], J. M. Miranda[2], F. Chierici[3, 4], and N. Zitellini[3]

SWAN - code





Our Goal:

To study

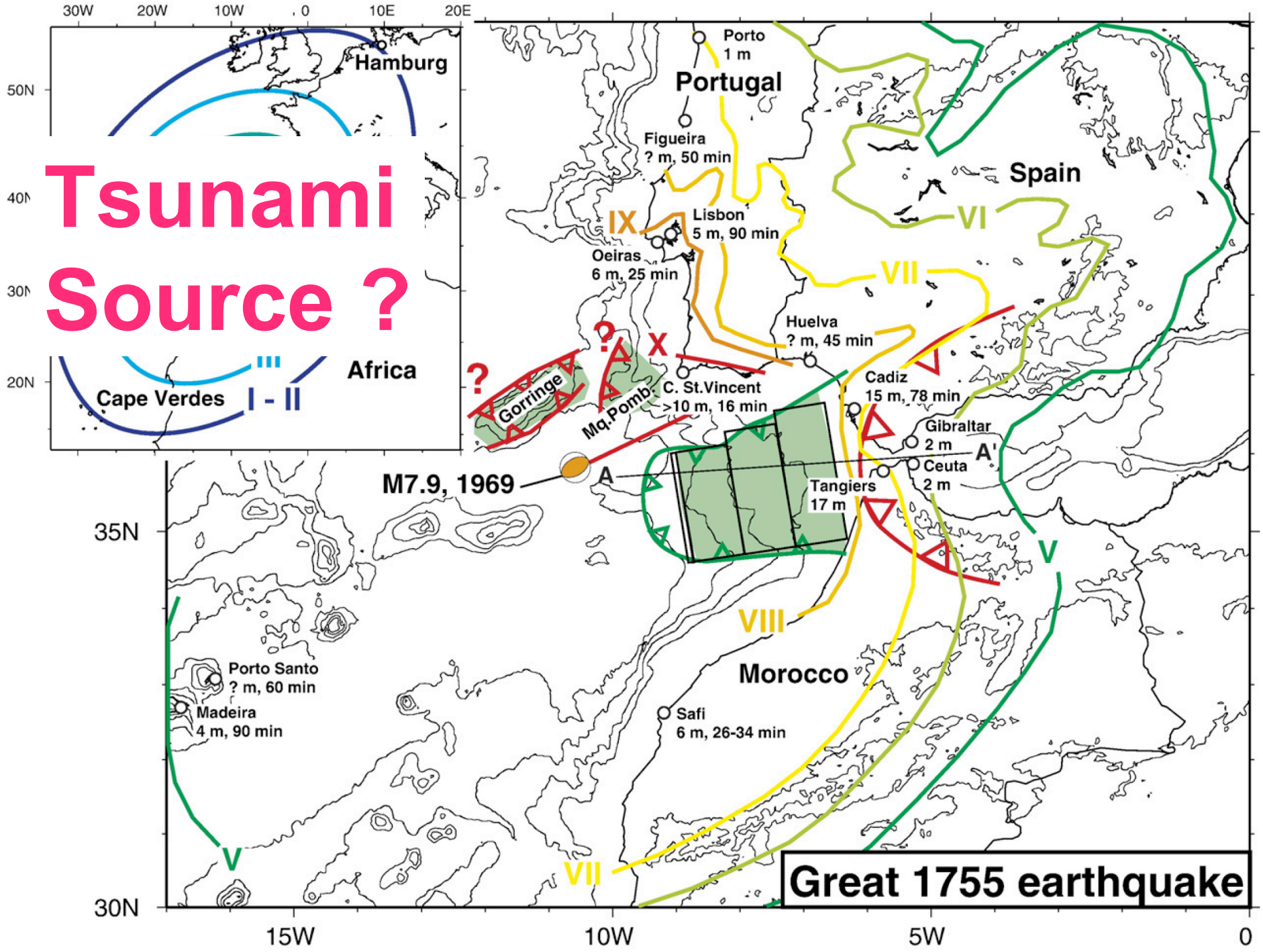
1755 Tsunami Effect

on French West Indies

"At St. Martin, the sea retired so far that a sloop, attached to its anchor in 4.6 m of water, was laid dry on her broadside.

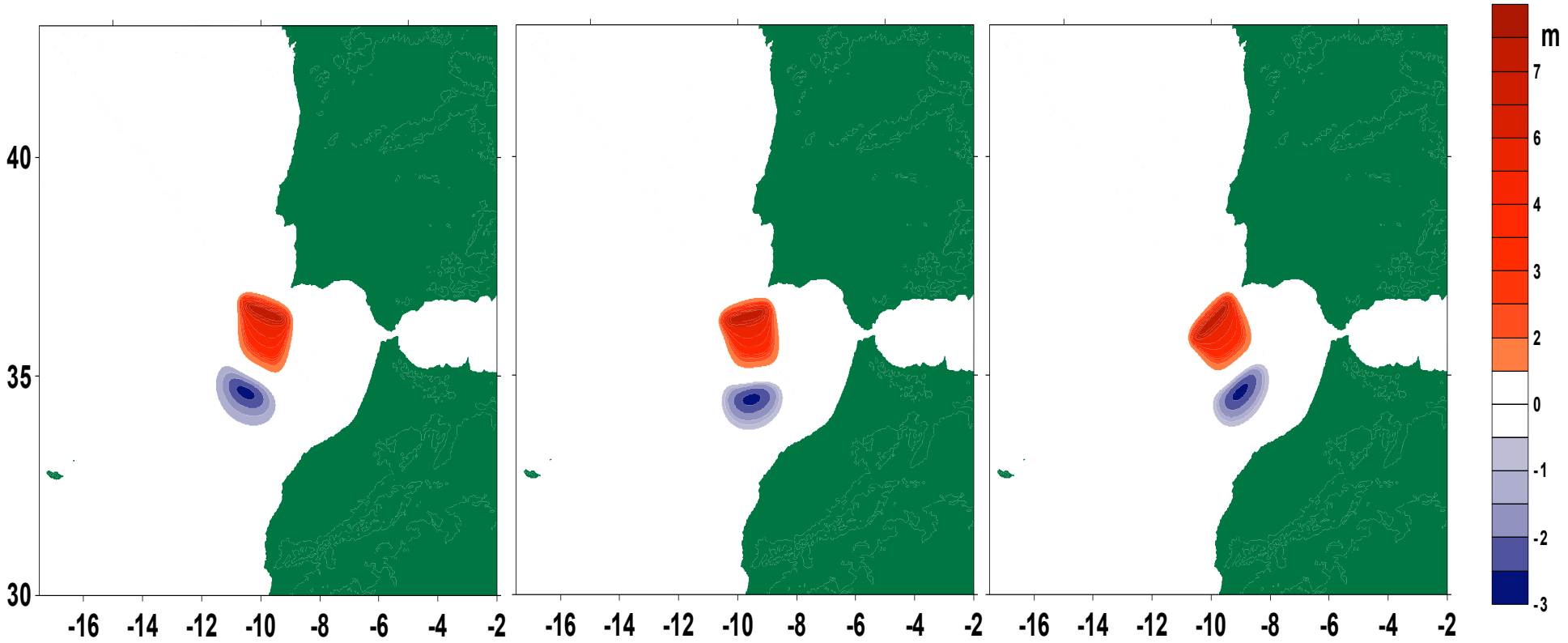
Recently, Morton et al (2006) found the probable geological evidence of the 1755 tsunami on the east coast of Grande-Terre (Guadeloupe) at Anse Ste. Marguerite and Anse Maurice on a height of 2-3 m

At Martinique, it overflowed the low land, and returned quickly to former boundaries. some places were left dry on approximately a mile (1.8 m)


Tsunami Source ?
30W
20W
10W
0
10E
20E
50N
40N
30N
20N
Hamburg
Cape Verdes
I - II
III
Africa
Porto
1 m
Portugal
Figueira
? m, 50 min
Spain
IX
Lisbon
5 m, 90 min
VI
Oeiras
6 m, 25 min
VII
Huelva
? m, 45 min
?
X
?
Gorringe
Mq.Pomb.
C. St.Vincent
>10 m, 16 min
Cadiz
15 m, 78 min
Gibraltar
2 m
A'
M7.9, 1969
A
Ceuta
2 m
Tangiers
17 m
V
VIII
Morocco
Porto Santo
? m, 60 min
Madeira
4 m, 90 min
Safi
6 m, 26-34 min
V
VII
Great 1755 earthquake
35N
30N
15W
10W
5W
0

Rupture parameters for 3 different source alternatives used in our study

Source	I/II/III
Focal Depth (km)	22
Fault Length (km)	180
Fault Width (km)	210
Slip Dislocation (m)	19
Dip Angle (deg)	15
Rake Angle (deg)	100
Strike Angle (deg. CW)	105/80/55
Maximum Positive Amplitude (m)	8.14
Minimum Negative Amplitude (m)	-2.66



Tsunami Sources (Okada Solution)

Three alternatives

Shallow Water Theory

$$\frac{\partial M}{\partial t}+\frac{1}{R\cos\grave{e}}\frac{\partial}{\partial\ddot{e}}\left(\frac{M^2}{D}\right)+\frac{1}{R\cos\grave{e}}\frac{\partial}{\partial\grave{e}}\left(\frac{MN\cos\grave{e}}{D}\right)+\frac{gD}{R\cos\grave{e}}\frac{\partial\varsigma}{\partial\ddot{e}}=fN$$

$$\frac{\partial N}{\partial t}+\frac{1}{R\cos\grave{e}}\frac{\partial}{\partial\ddot{e}}\left(\frac{MN}{D}\right)+\frac{1}{R\cos\grave{e}}\frac{\partial}{\partial\grave{e}}\left(\frac{N^2\cos\grave{e}}{D}\right)+\frac{gD}{R}\frac{\partial\varsigma}{\partial\grave{e}}=-fM$$

$$\frac{\partial\varsigma}{\partial t}+\frac{1}{R\cos\grave{e}}\left[\frac{\partial M}{\partial\ddot{e}}+\frac{\partial}{\partial\grave{e}}(N\cos\grave{e})\right]=0$$

h **is the water surface displacement,**

M **and** ***N*** **are components of water discharge fluxes**

D = h(x,y) + h **is the total water depth**

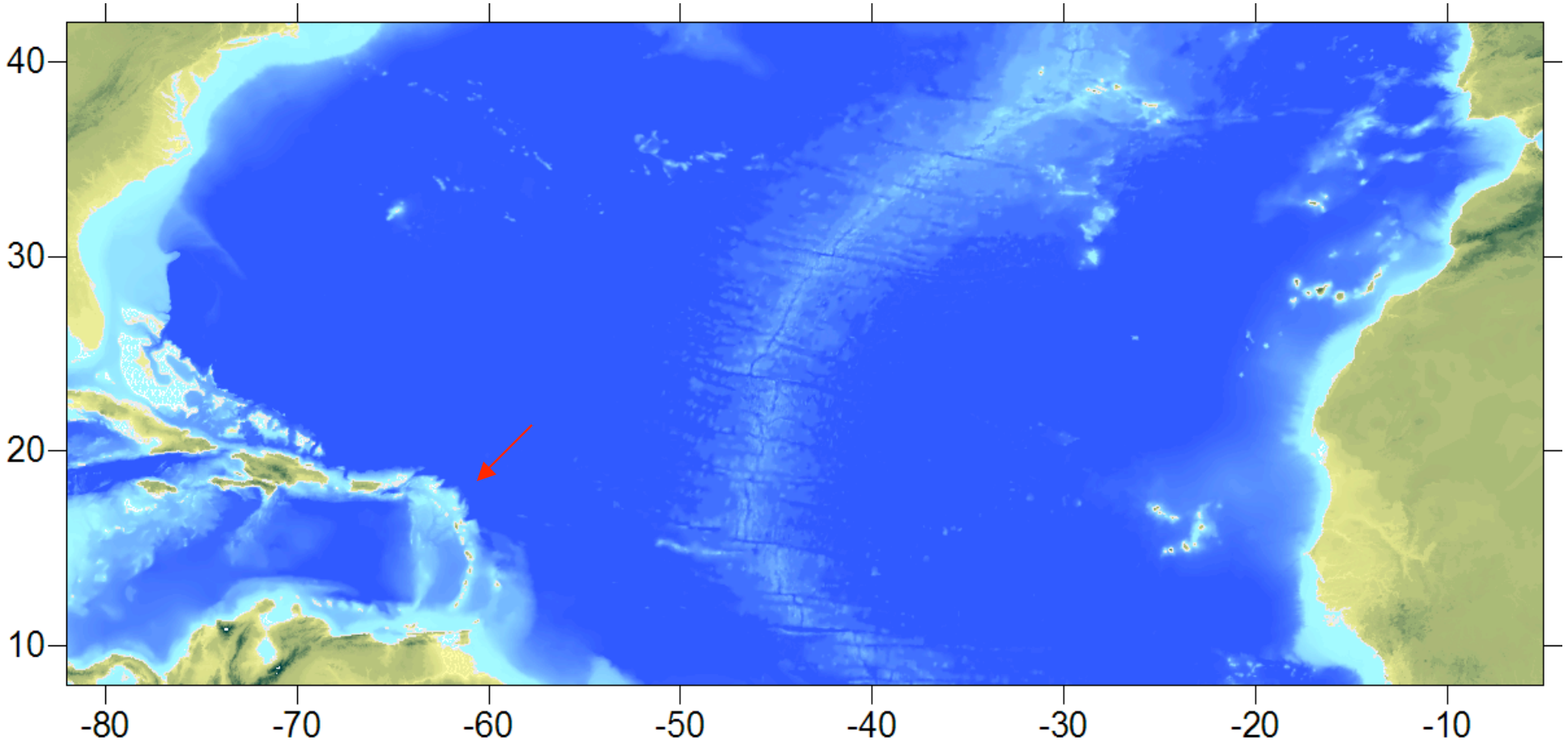
Numerical Code NAMI DANCE

NAMI DANCE was tested, validated and verified together with other internationally accredited tsunami computational tools (such as MOST, TUNAMI N2, COMCOT) in the Project acronymed TRANSFER (Tsunami Risk And Strategies for European Region) funded by the European Commission.

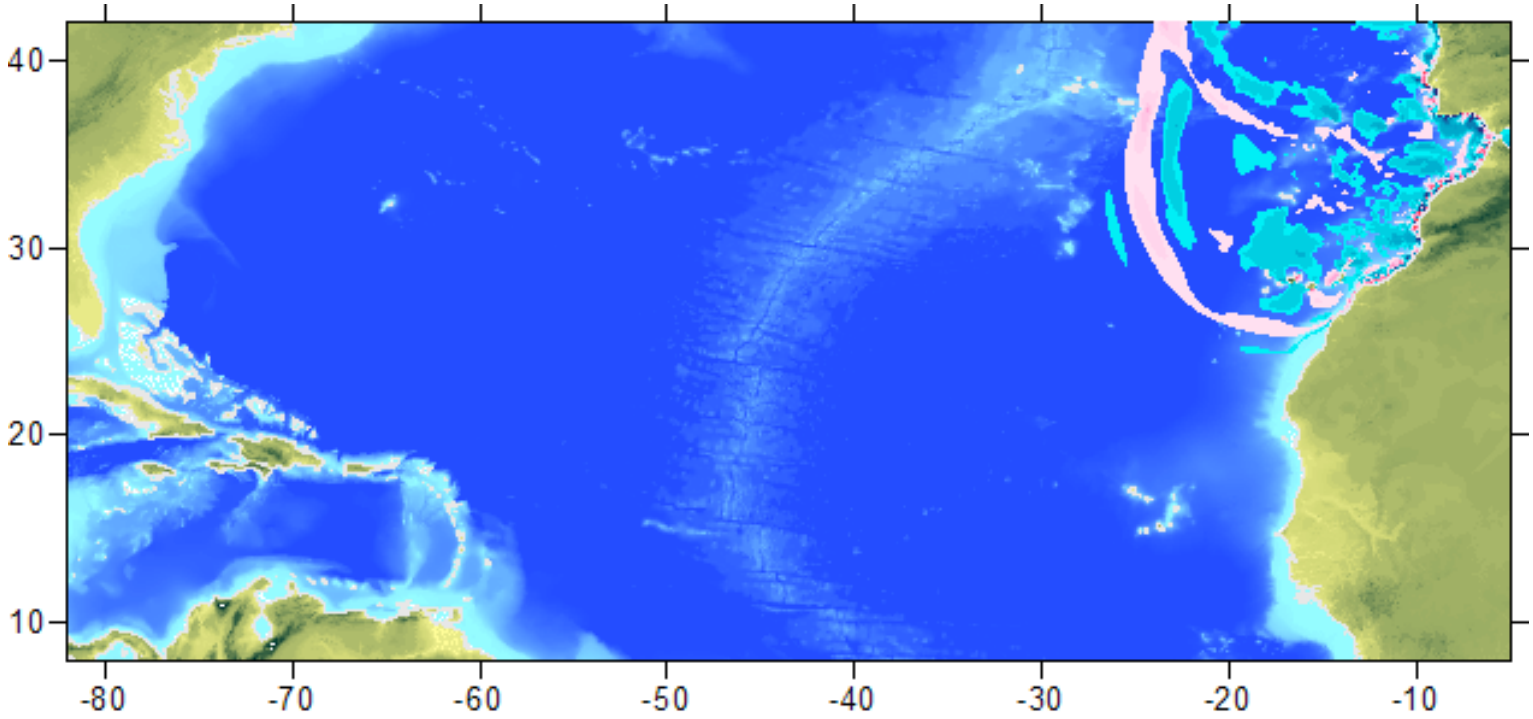
http://namidance.ce.metu.edu.tr

Domain

1 min (*GEBCO Digital Atlas, British Oceanographic Data Centre*)

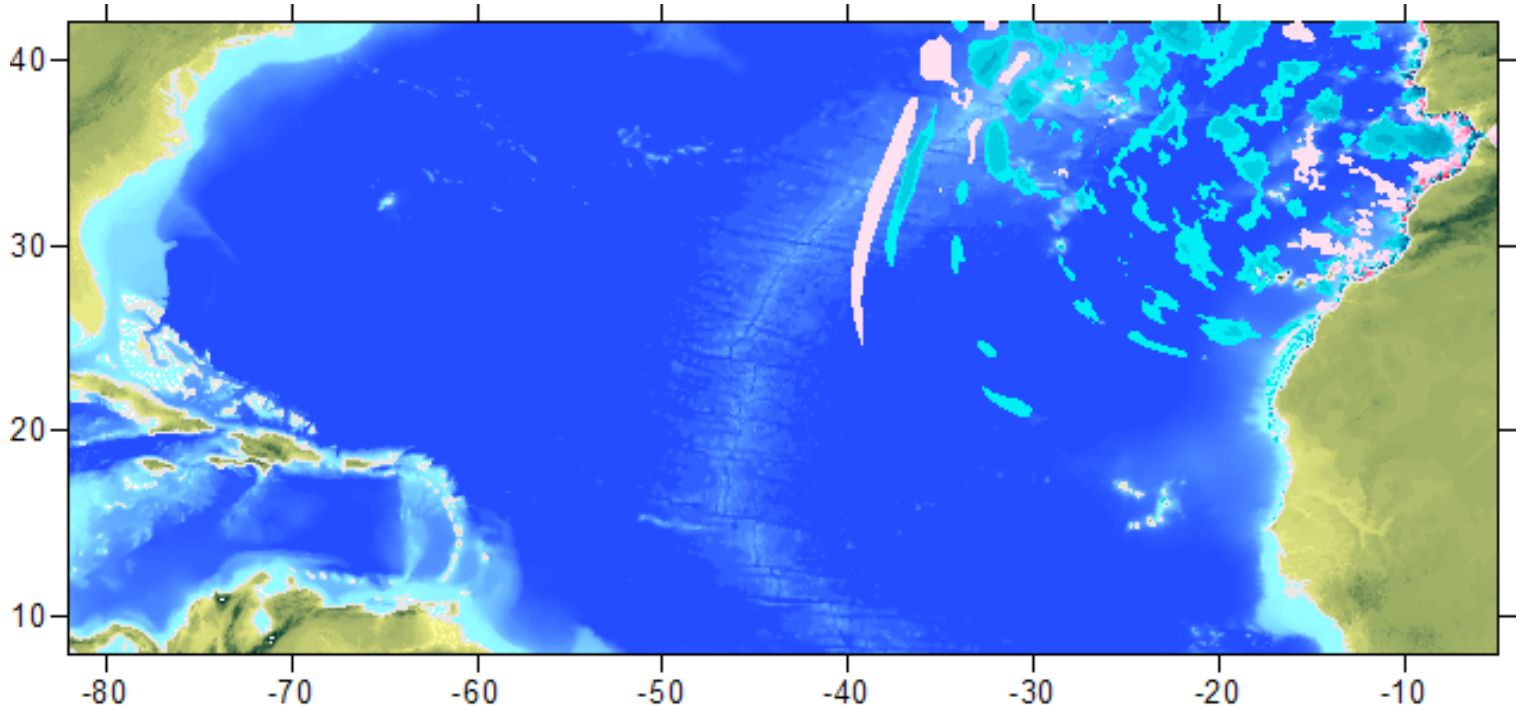


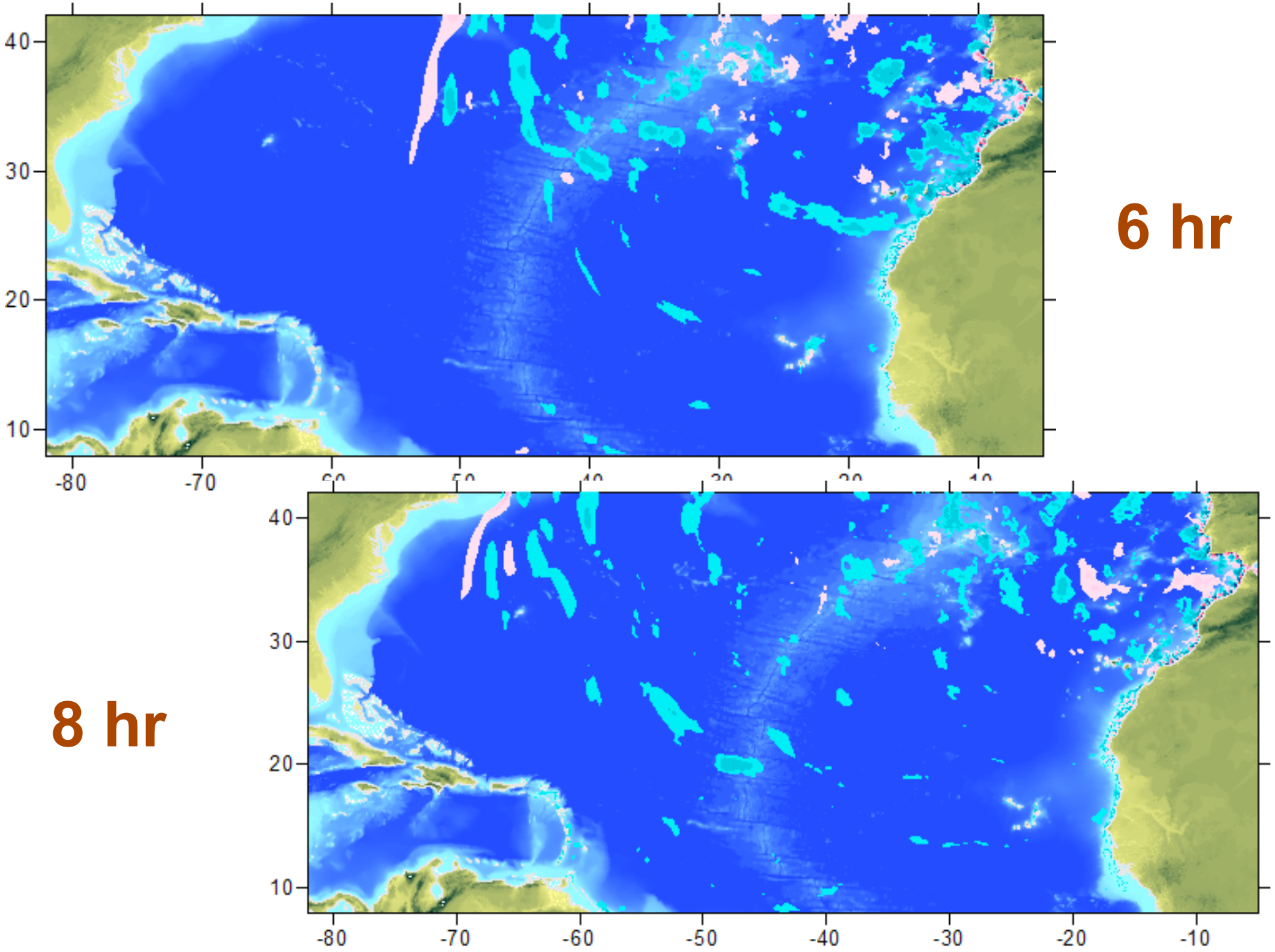
Full reflection on land; free passage on open boundaries

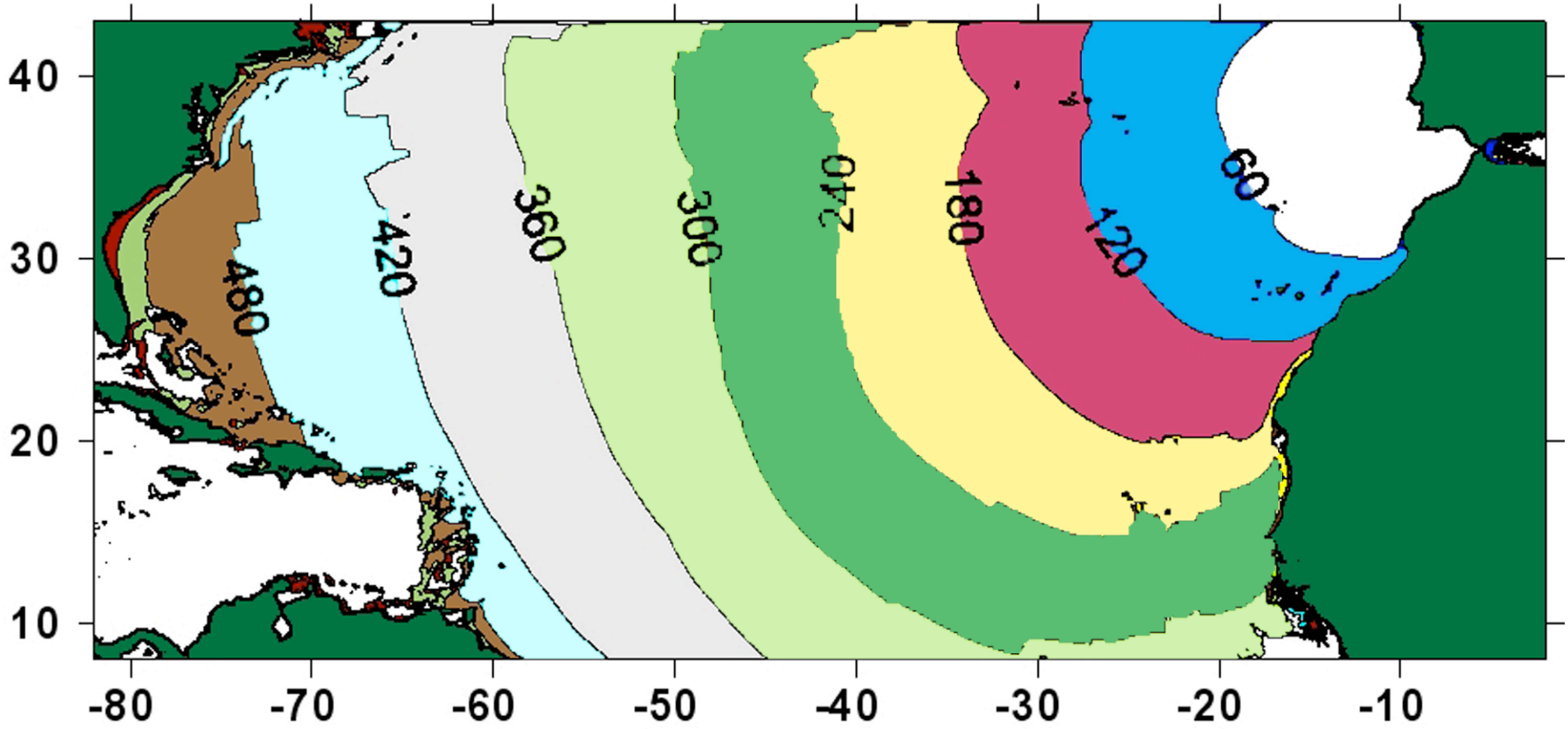


2 hr

4 hr

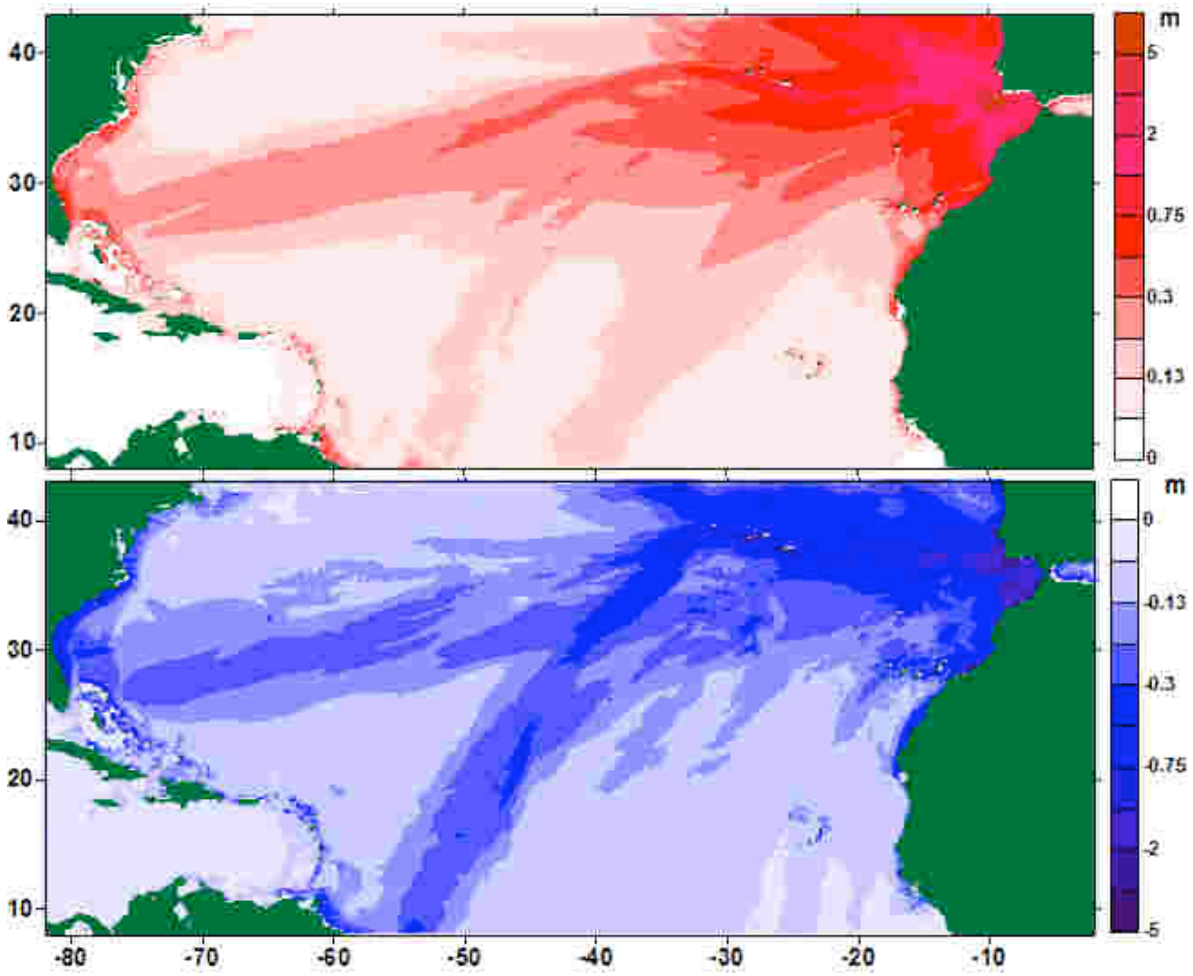



40
30
20
10
-80
-70
-60
-50
-40
-30
-20
-10
6 hr
8 hr



Tsunami travel time in minutes (Source Alternative I)

Exceeding 15 cm of uplift or subsidence



Florida and Bahamas
(20 cm in the open ocean,
up to 1 m near Bahamas)

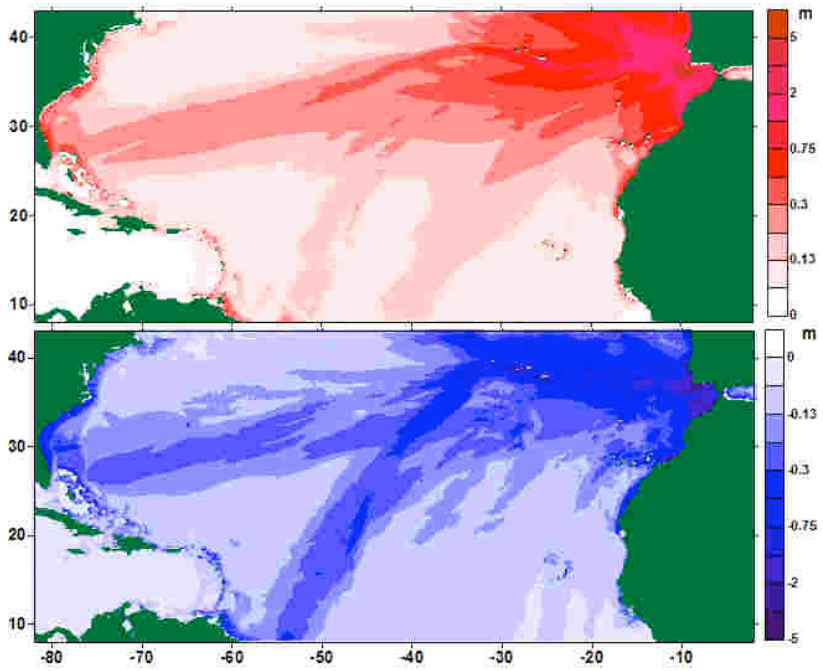
Maximum Amplitude

Minimum Amplitude

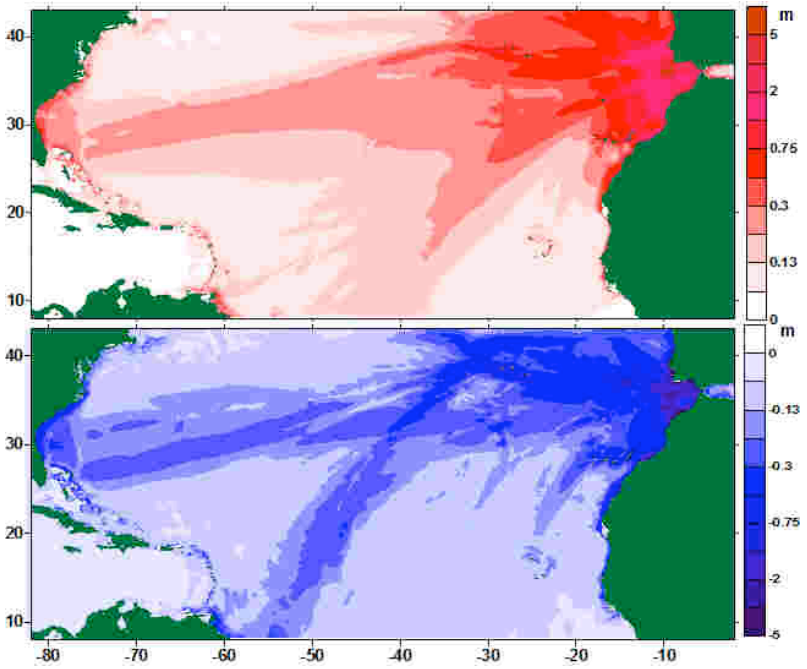
Source 1

Brazil
(-20 cm in the ocean)

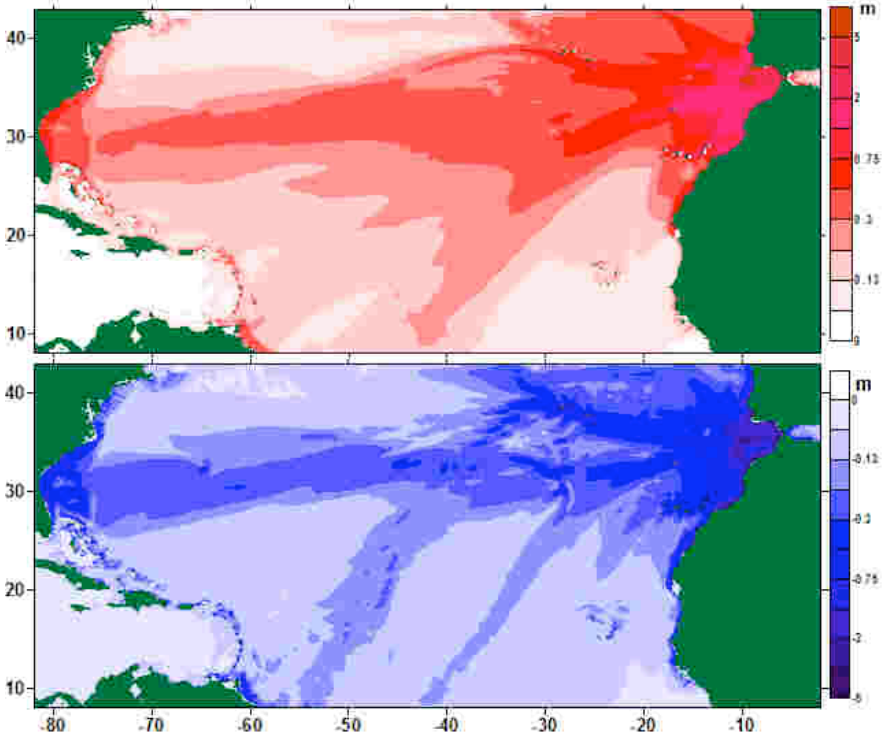
Distribution of amplitudes of tsunami waves in Atlantics



Source 1



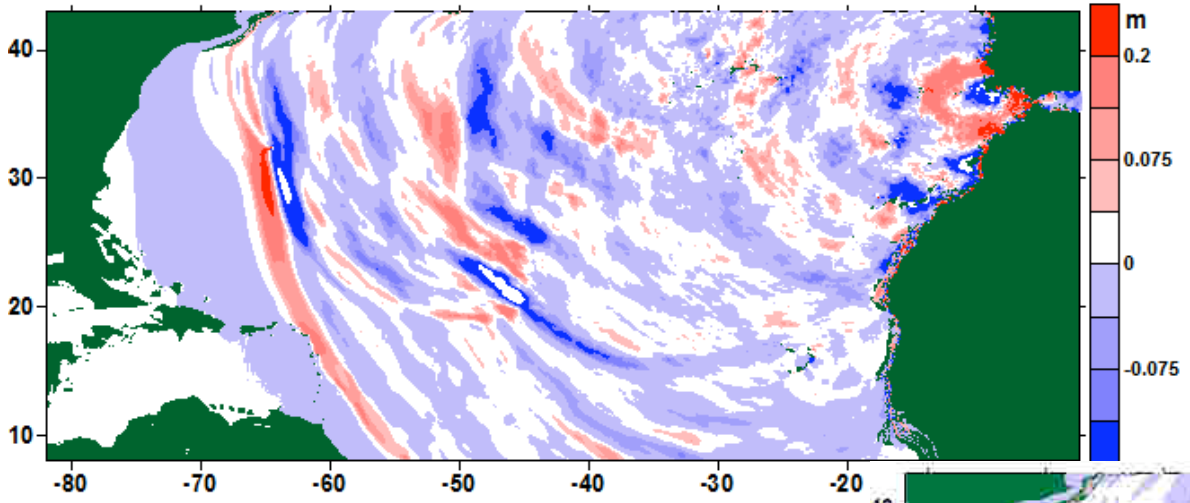
Source 2



Source 3

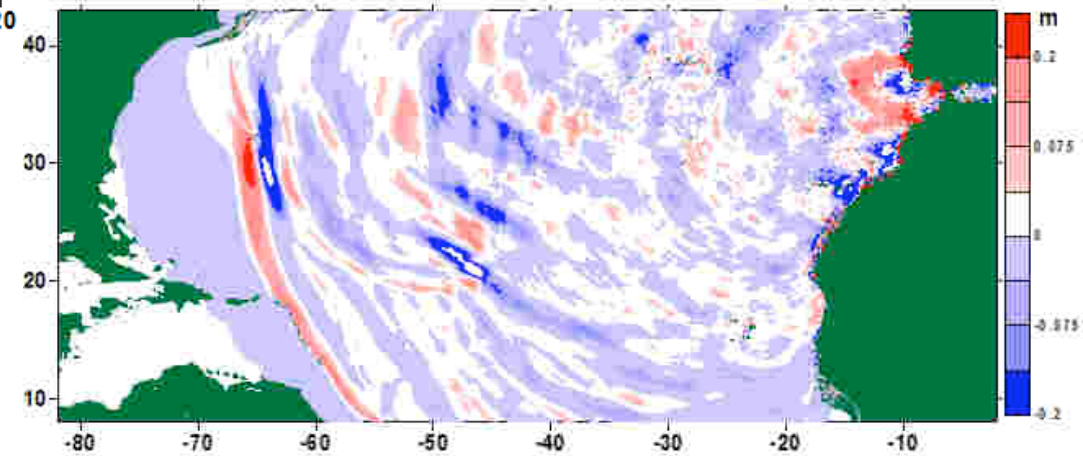
The main conclusion from the simulations is that in the case of tsunami generated in the vicinity of the Portuguese coast, the tsunami energy is directed towards Brazilian and Florida coasts and the region near Lesser Antiles remains less affected.

Similar results have recently been obtained by Lovholt et al (2008), who studied tsunami source located near the Canary Islands, and it demonstrates similar characteristics of tsunami propagation in the Atlantics.

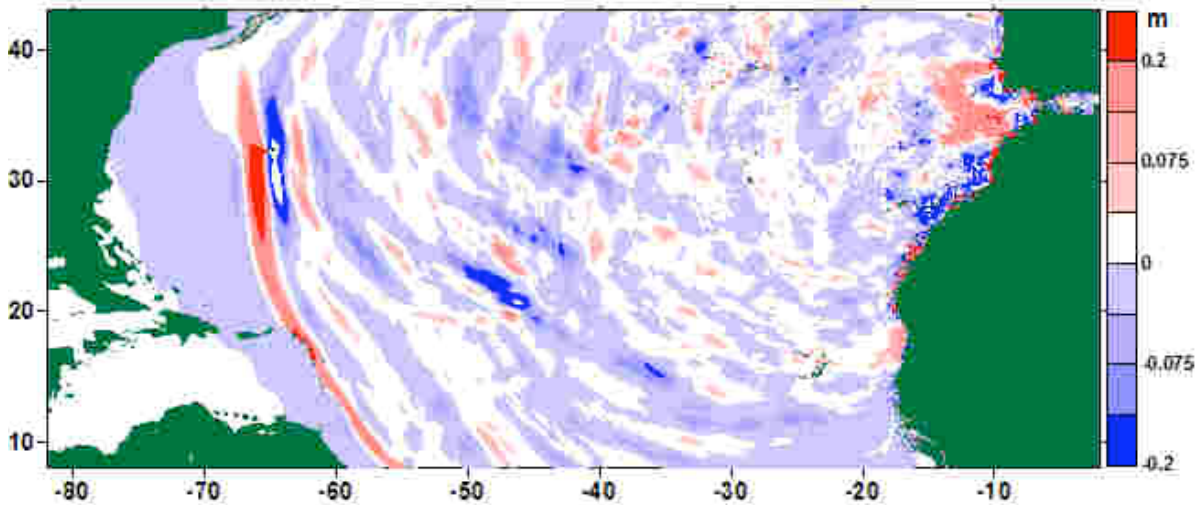


Source 1

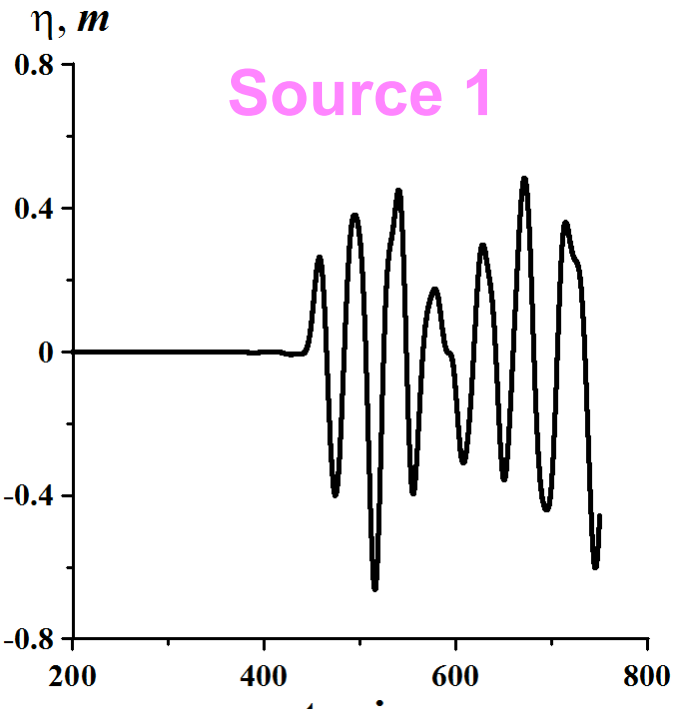
Snapshots,
7 hours

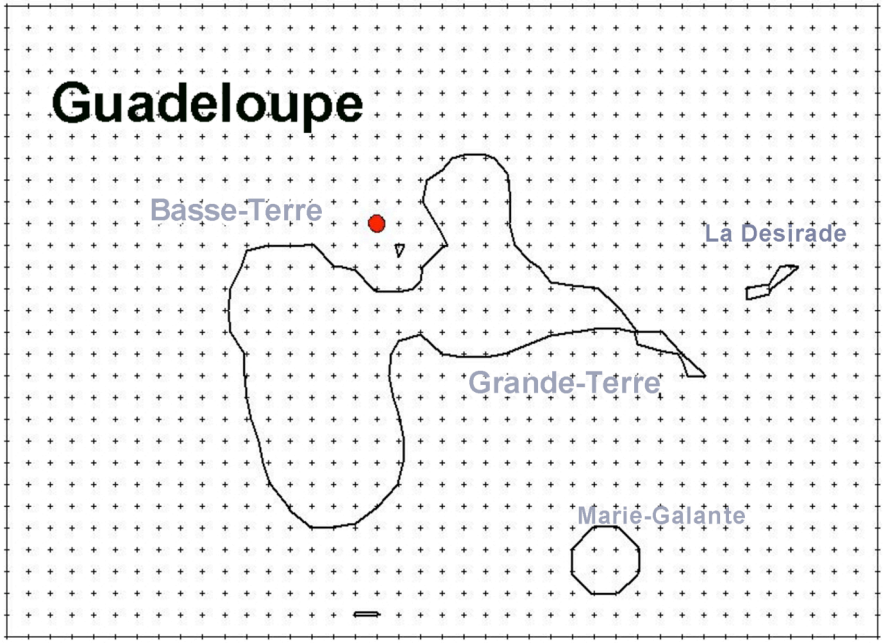


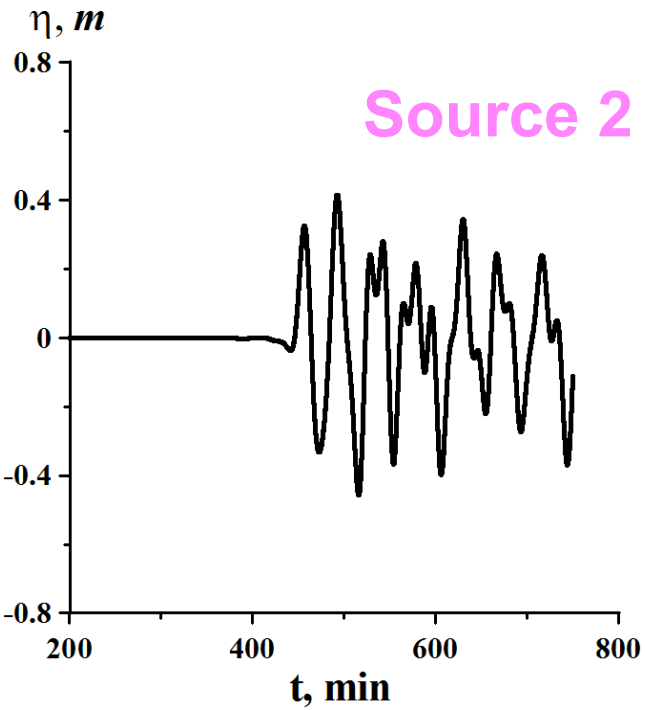
Source 2



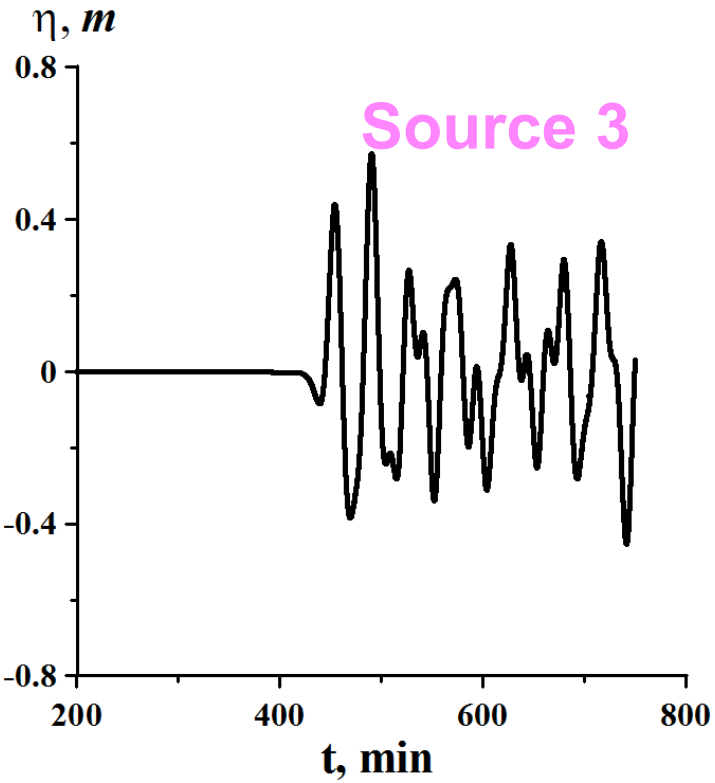
Source 3







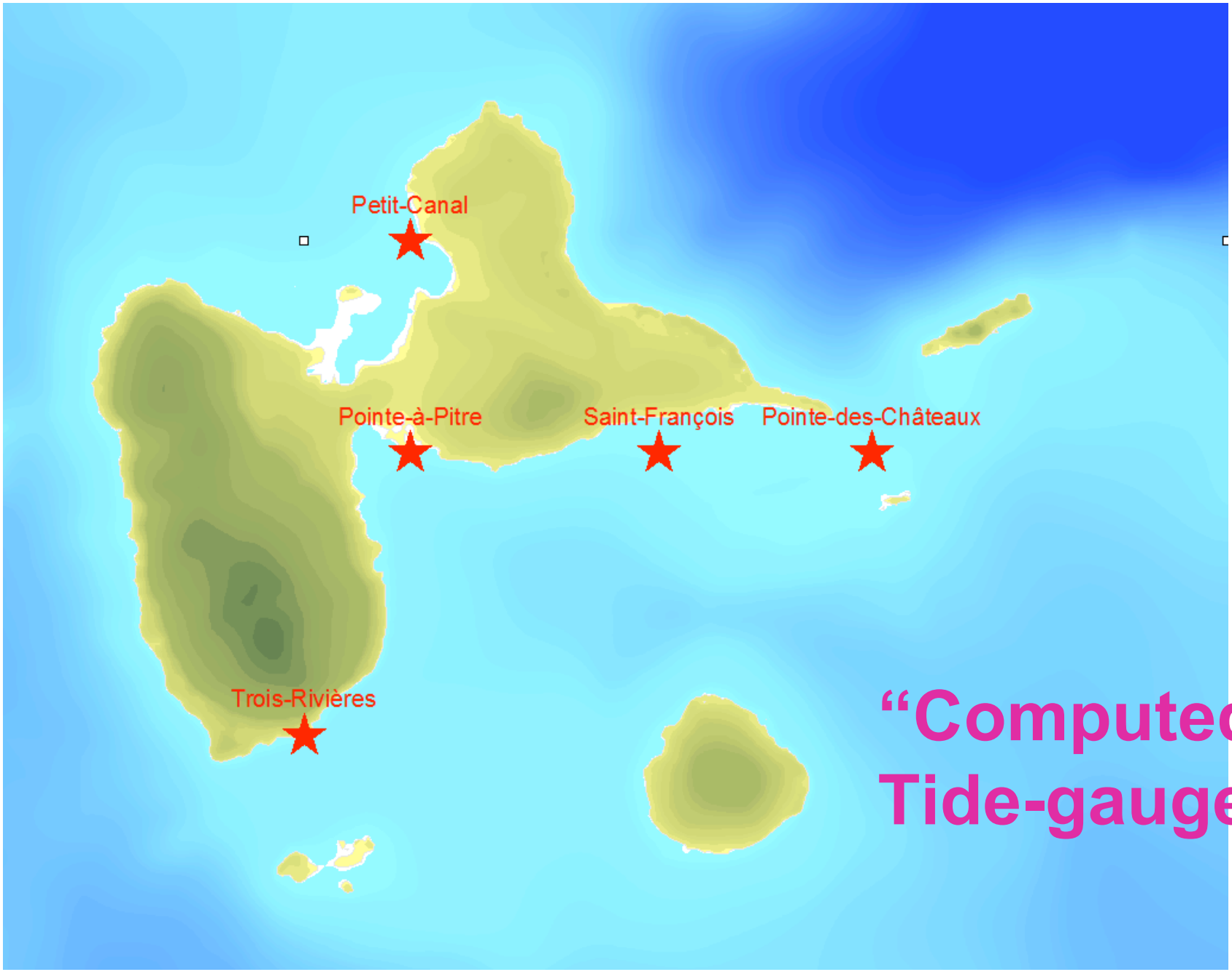
Synthetic Tide-gauge Record Northern Guadeloupe

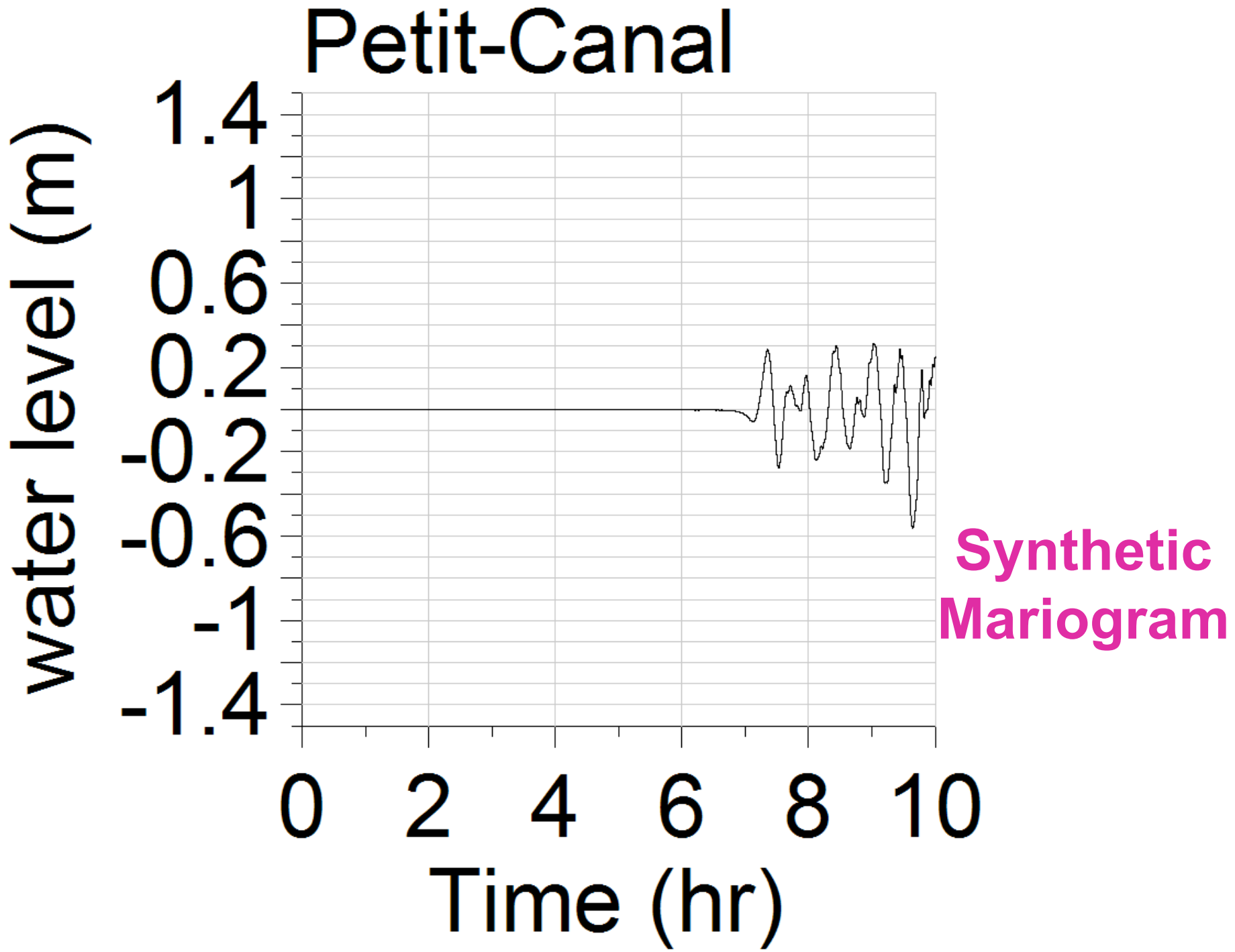


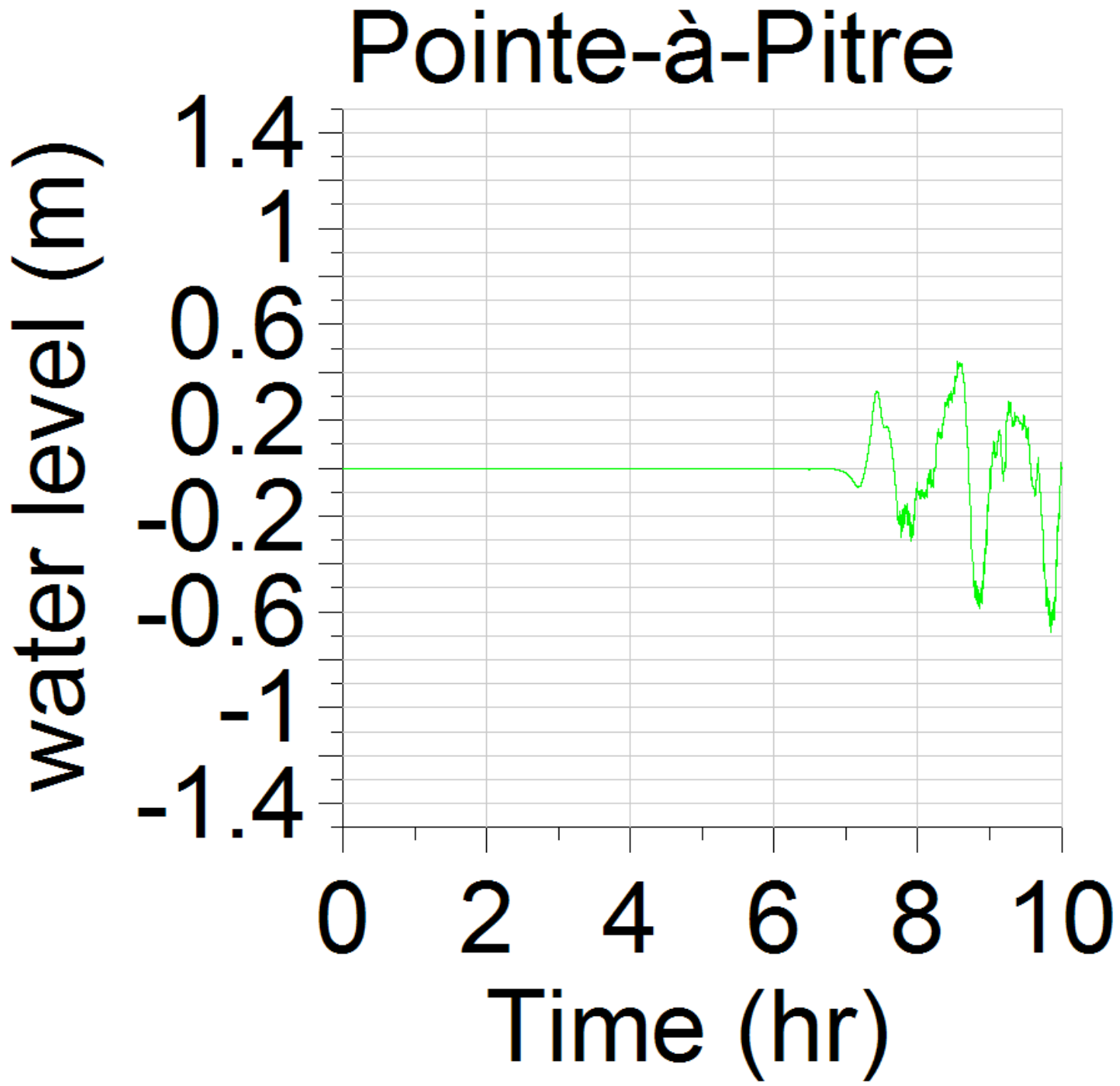
Computed Wave Amplitudes
at north of Guadeloupe are 40 - 50 cm
(wave height is approximately 1 m).

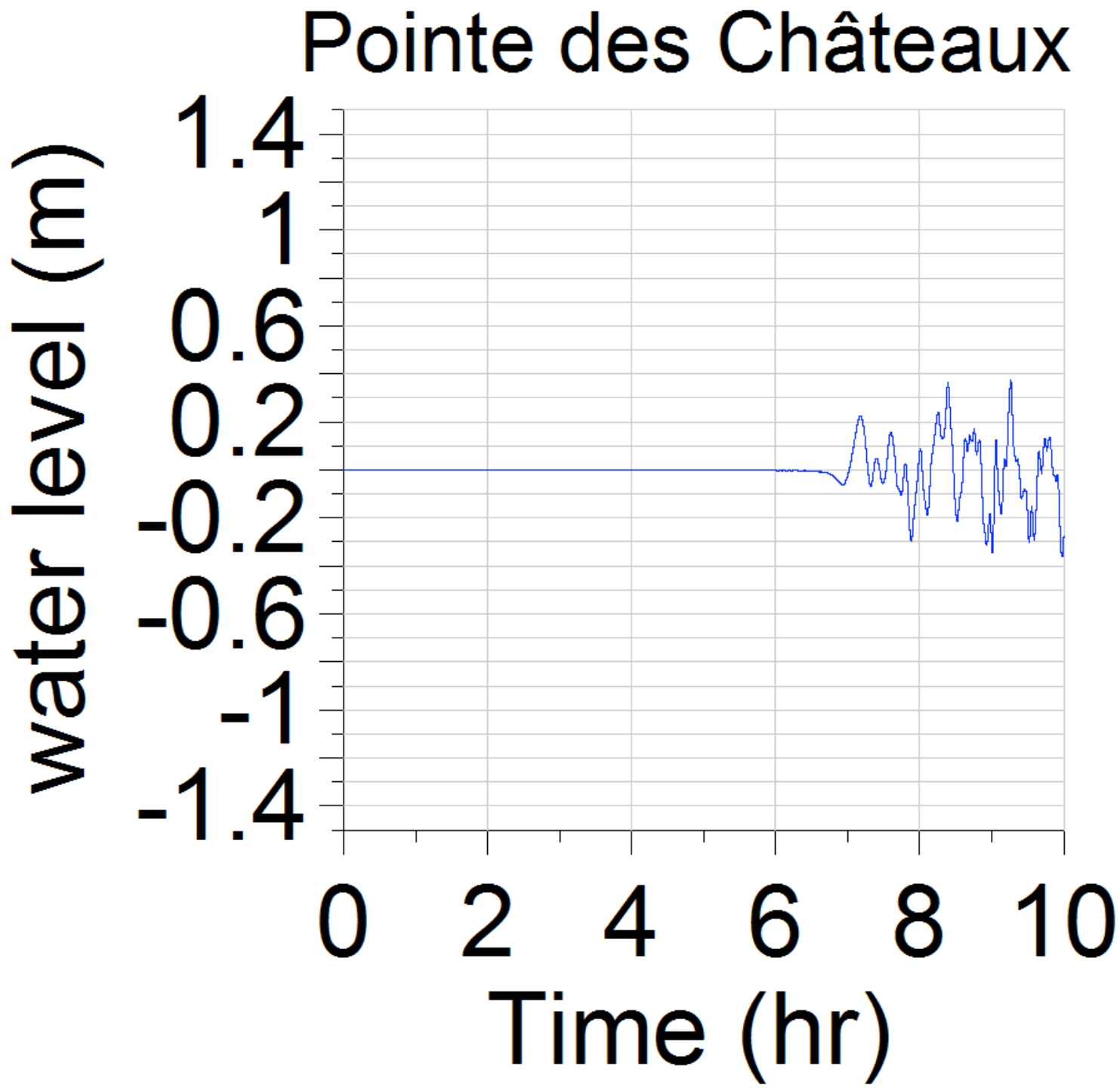
Runup ratio for the tsunami is 2-3

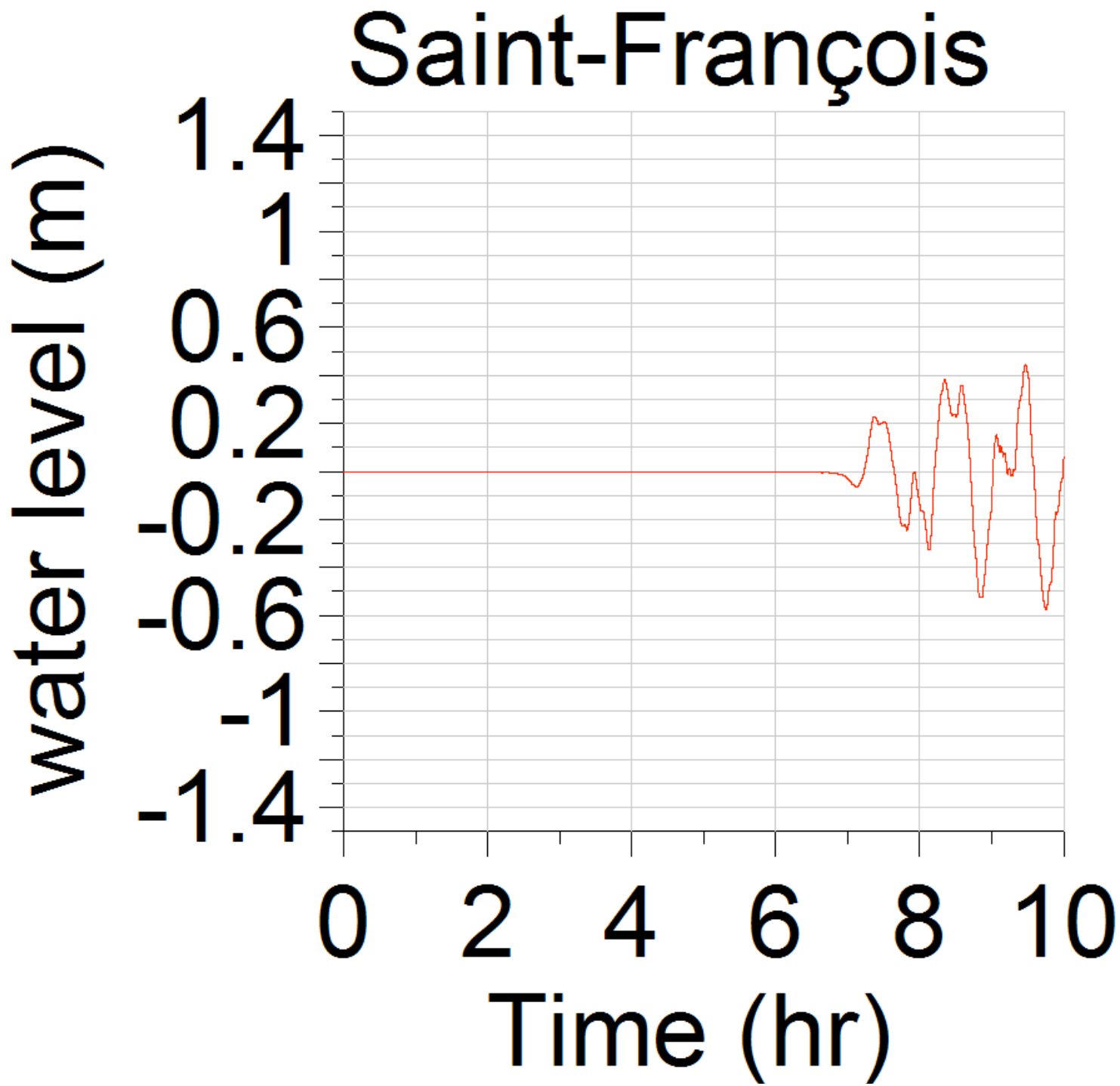
Tsunami runup height can reach 1 – 1.5 m

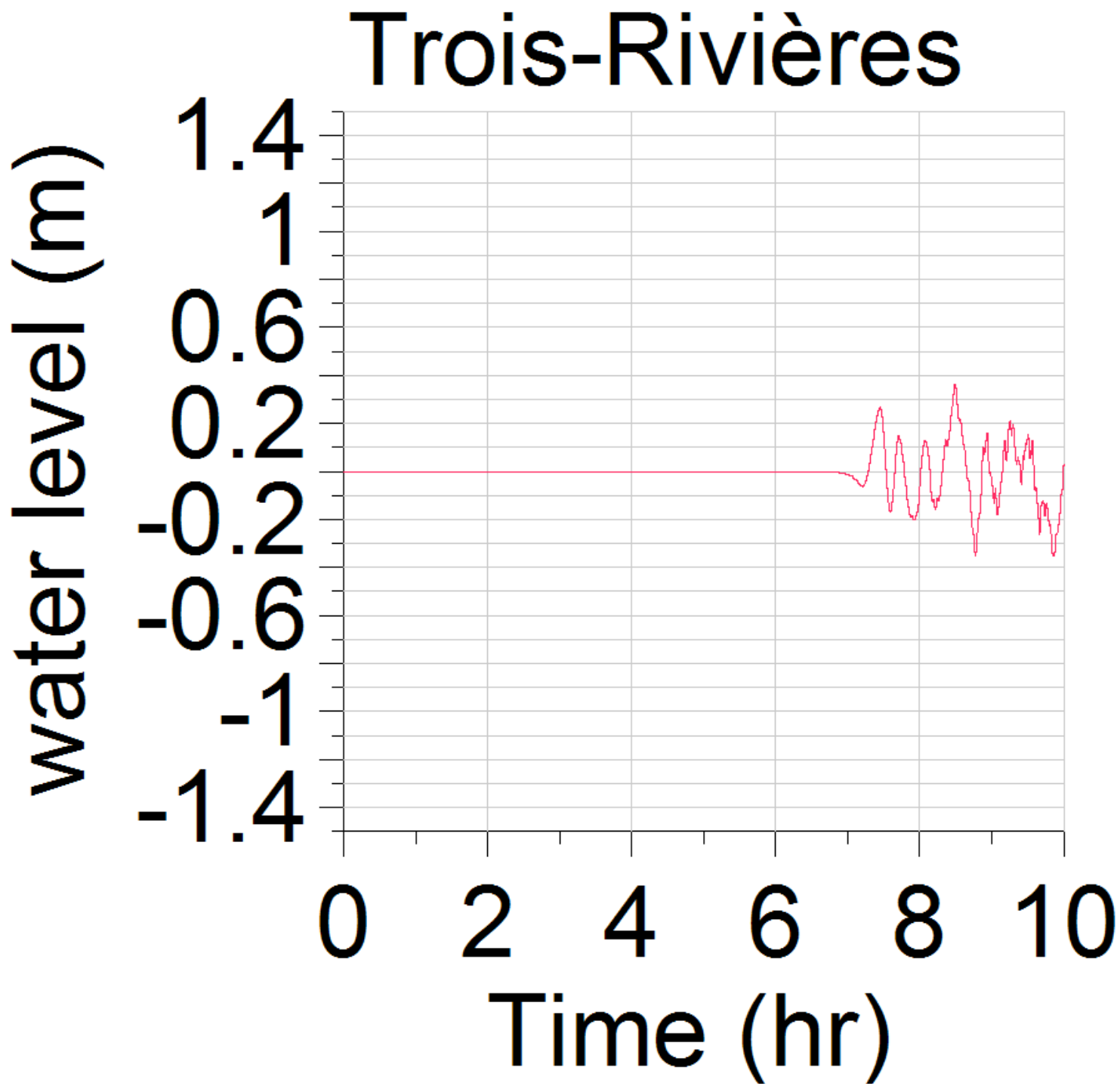

Petit-Canal
Pointe-à-Pitre
Saint-François
Pointe-des-Châteaux
Trois-Rivières
“Computed”
Tide-gauge

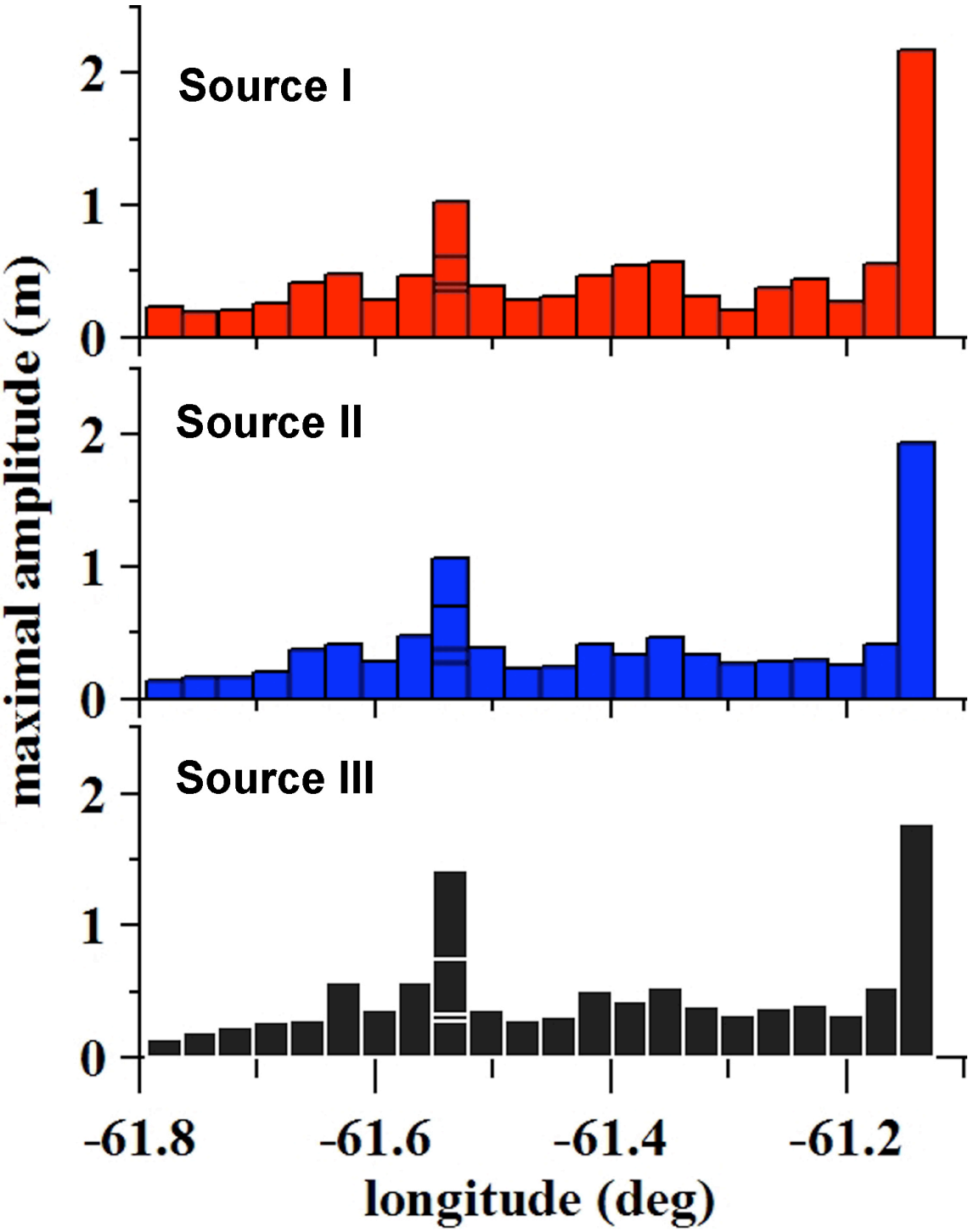

Petit-Canal
water level (m)
1.4
1
0.6
0.2
-0.2
-0.6
-1
-1.4
0
2
4
6
8
10
Time (hr)
Synthetic
Mariogram


Pointe-à-Pitre
water level (m)
1.4
1
0.6
0.2
-0.2
-0.6
-1
-1.4
0
2
4
6
8
10
Time (hr)

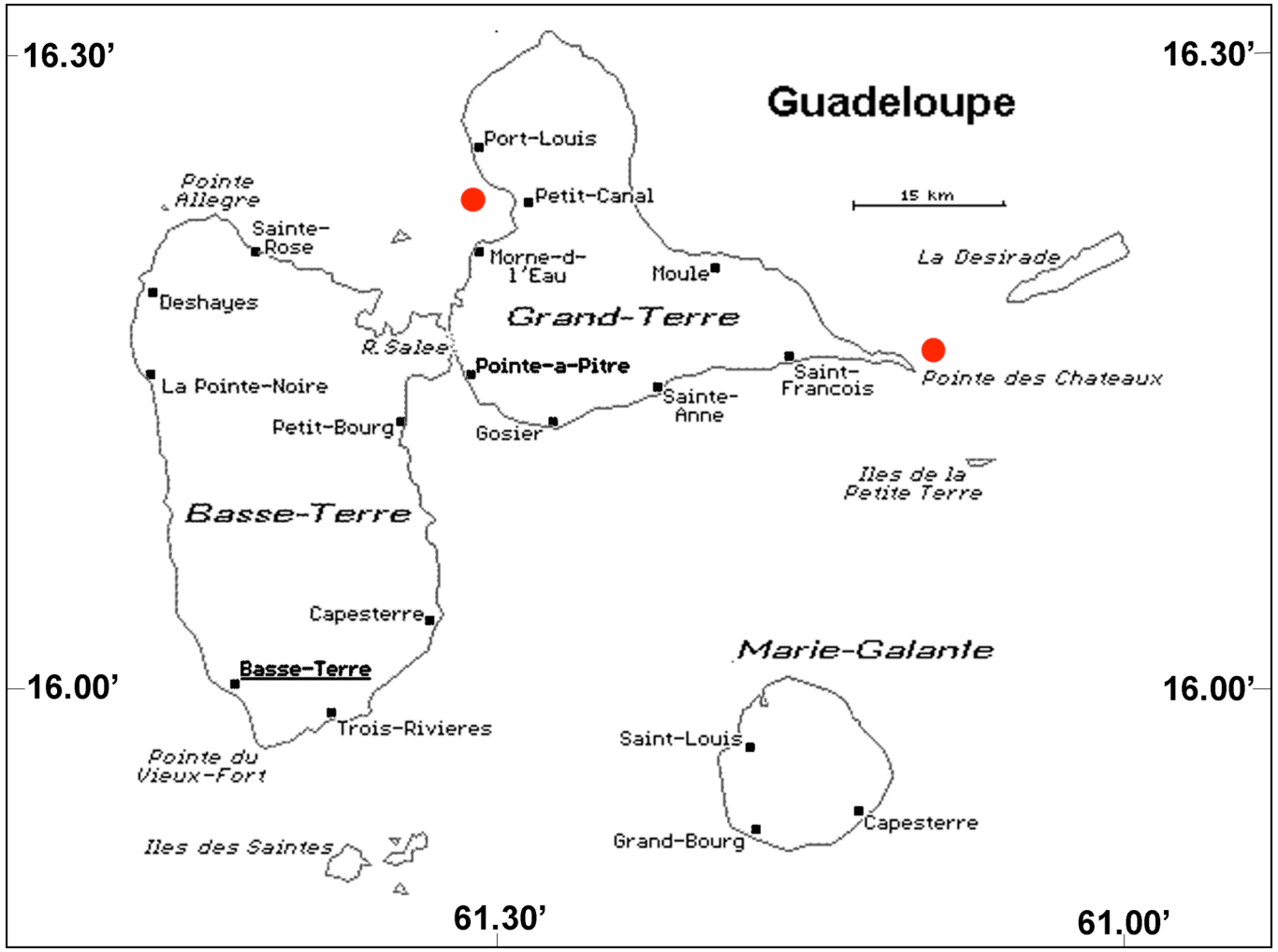

Pointe des Châteaux
water level (m)
1.4
1
0.6
0.2
-0.2
-0.6
-1
-1.4
0
2
4
6
8
10
Time (hr)


Saint-François
water level (m)
1.4
1
0.6
0.2
-0.2
-0.6
-1
-1.4
0
2
4
6
8
10
Time (hr)


Trois-Rivières
water level (m)
1.4
1
0.6
0.2
-0.2
-0.6
-1
-1.4
0
2
4
6
8
10
Time (hr)



Distribution of tsunami amplitudes along northern and north-eastern coasts of Guadeloupe



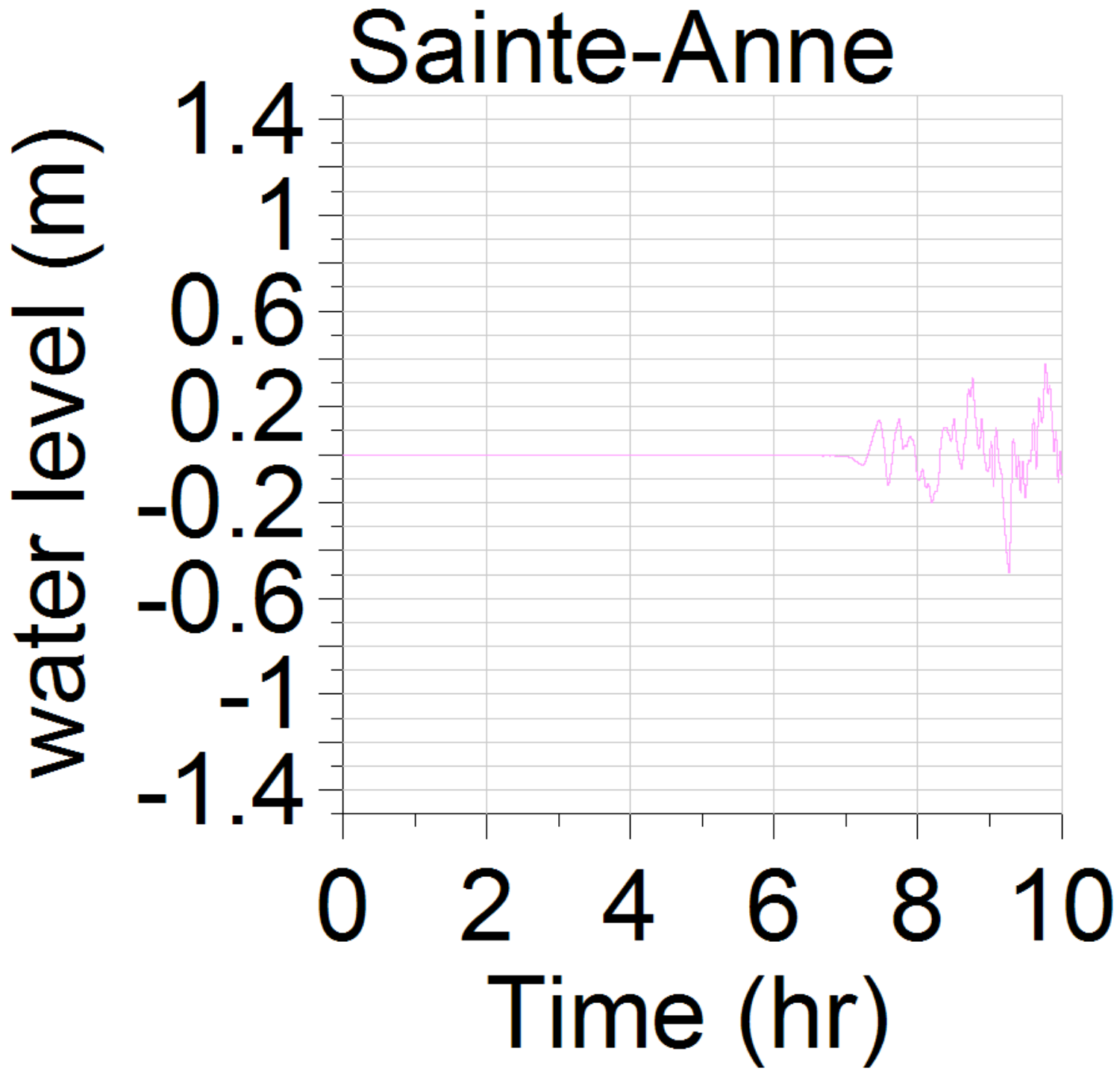
Red points - locations where tsunami amplitude exceeds 1m

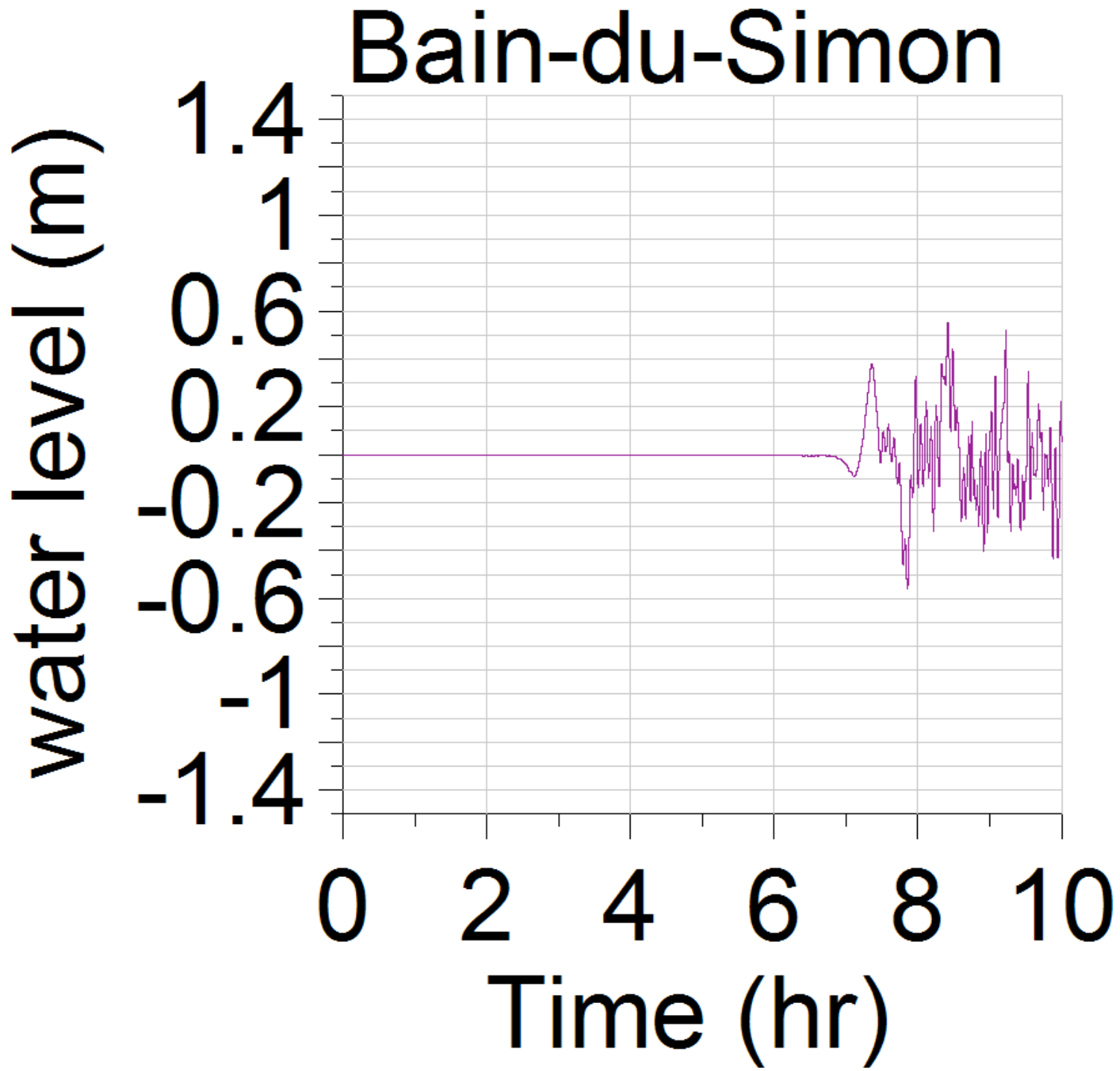
Point des Chateaux, 2.17 m; Petit-Canal, 1.42 m

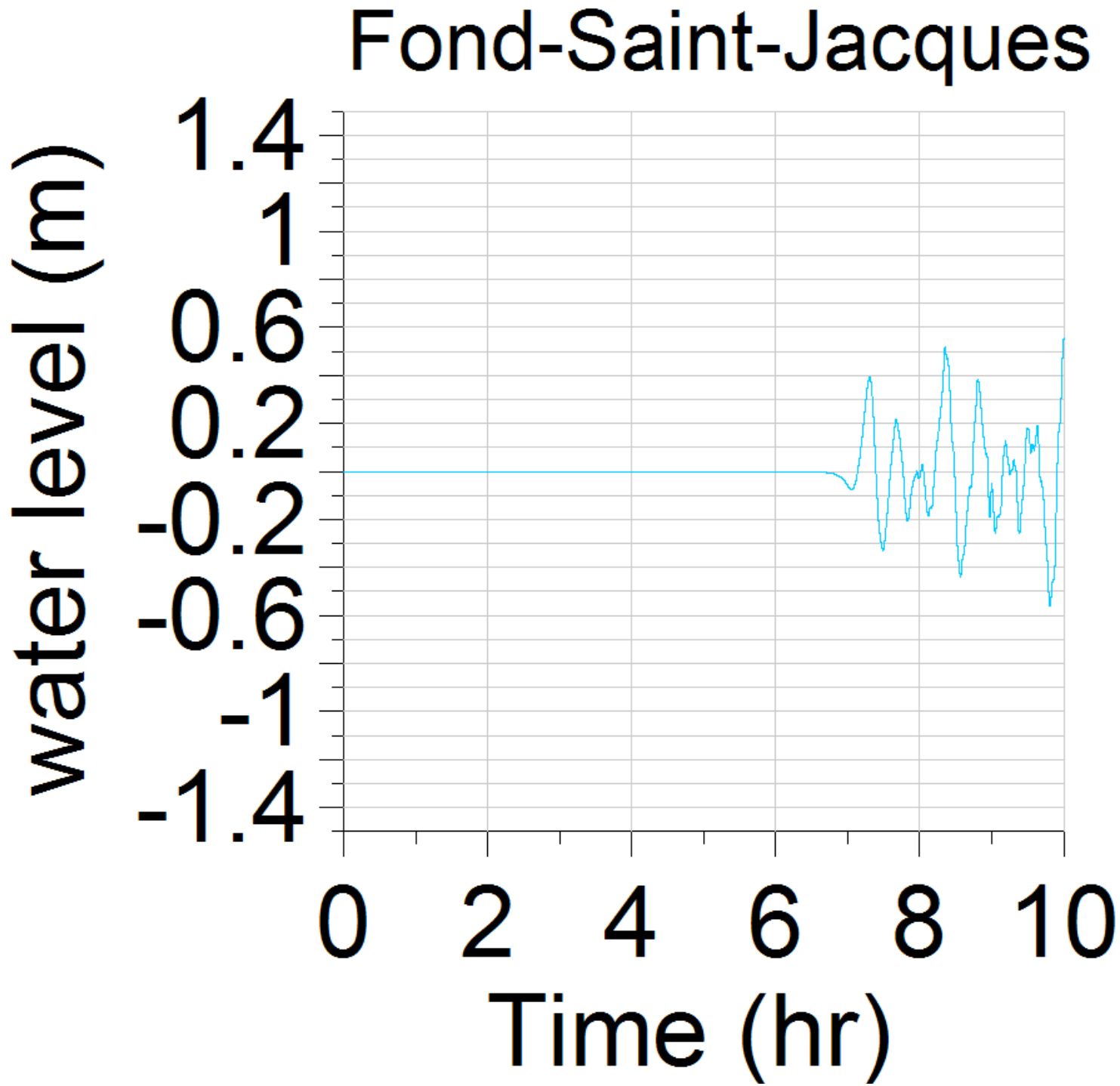
Pointe à Bacchus, near Petit-Bourg, 0.95 m

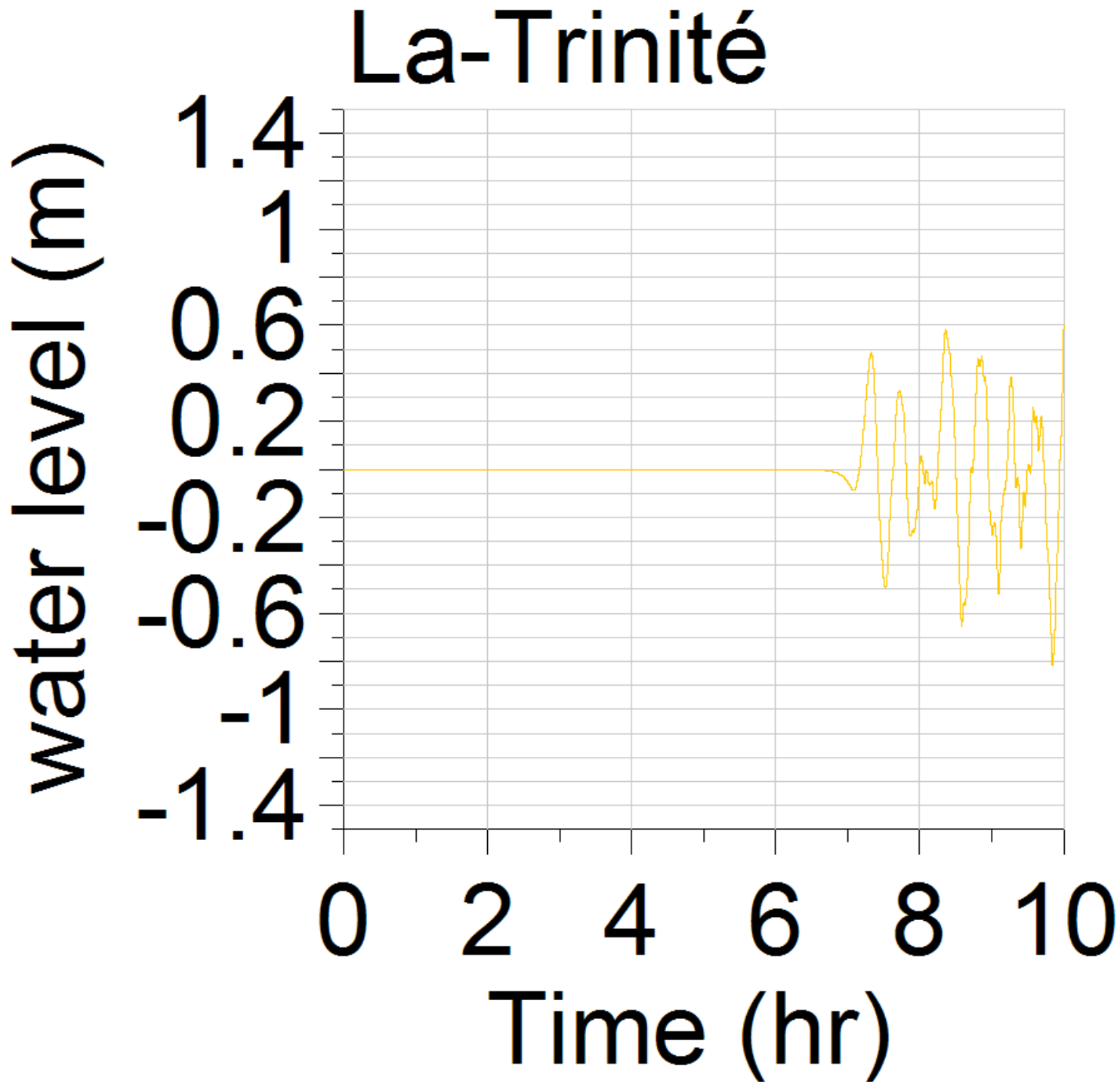

Fond-Saint-Jacques
La-Trinité
Pointe-de-la-Batterie
Pointe-Banane
Bain-du-Simon
Sainte-Anne

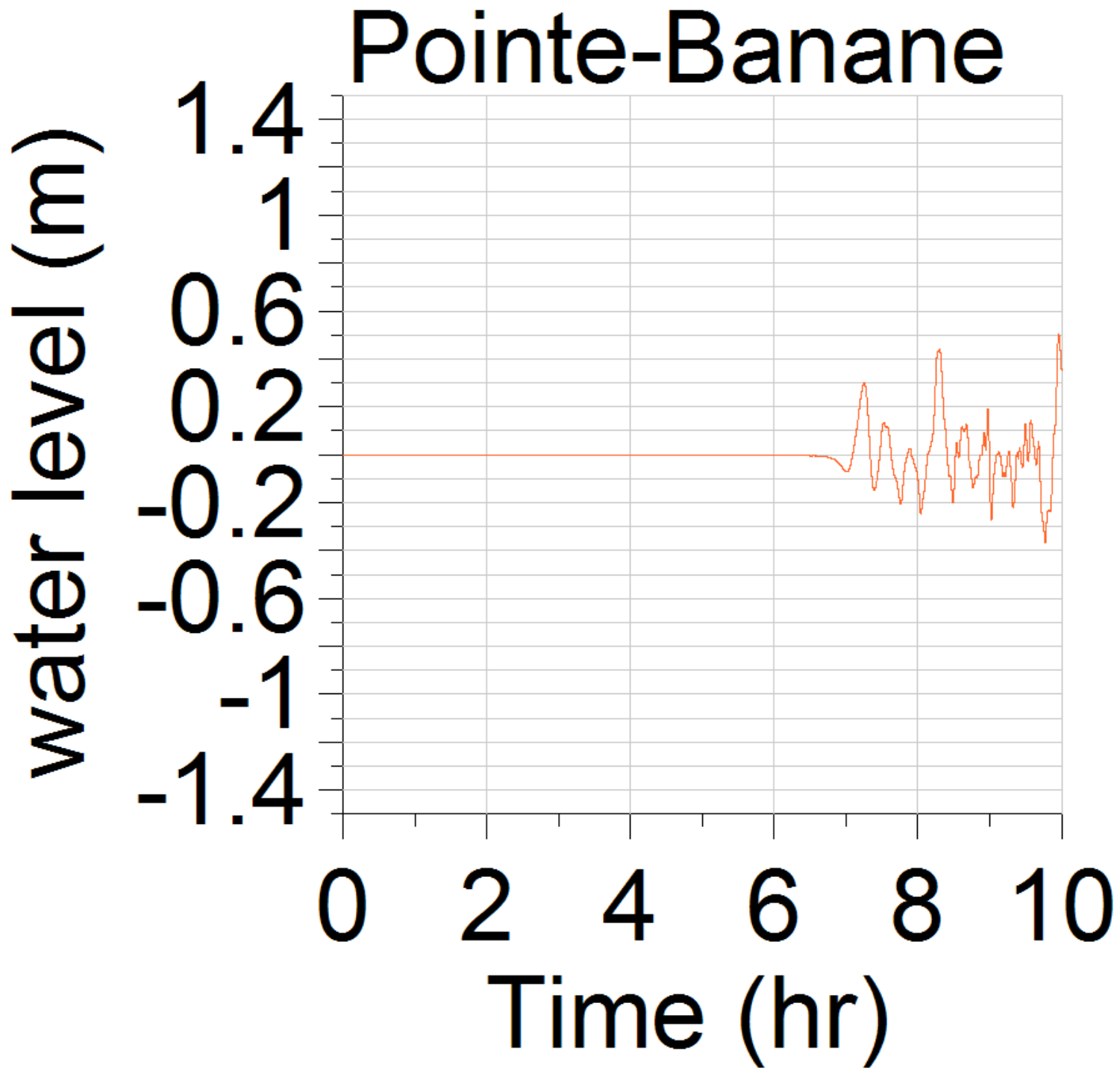
Martinique

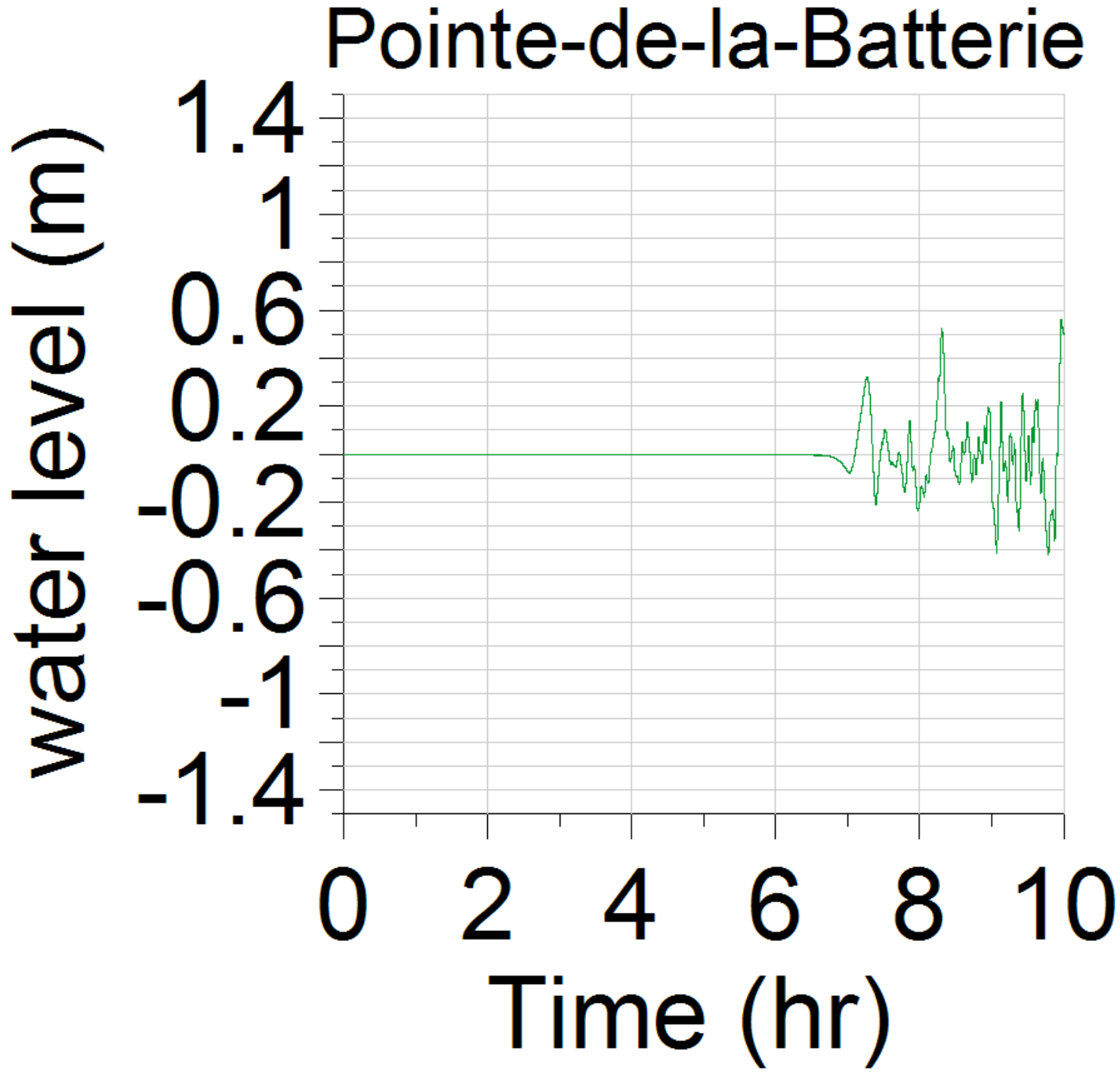

Sainte-Anne
water level (m)
1.4
1
0.6
0.2
-0.2
-0.6
-1
-1.4
0
2
4
6
8
10
Time (hr)

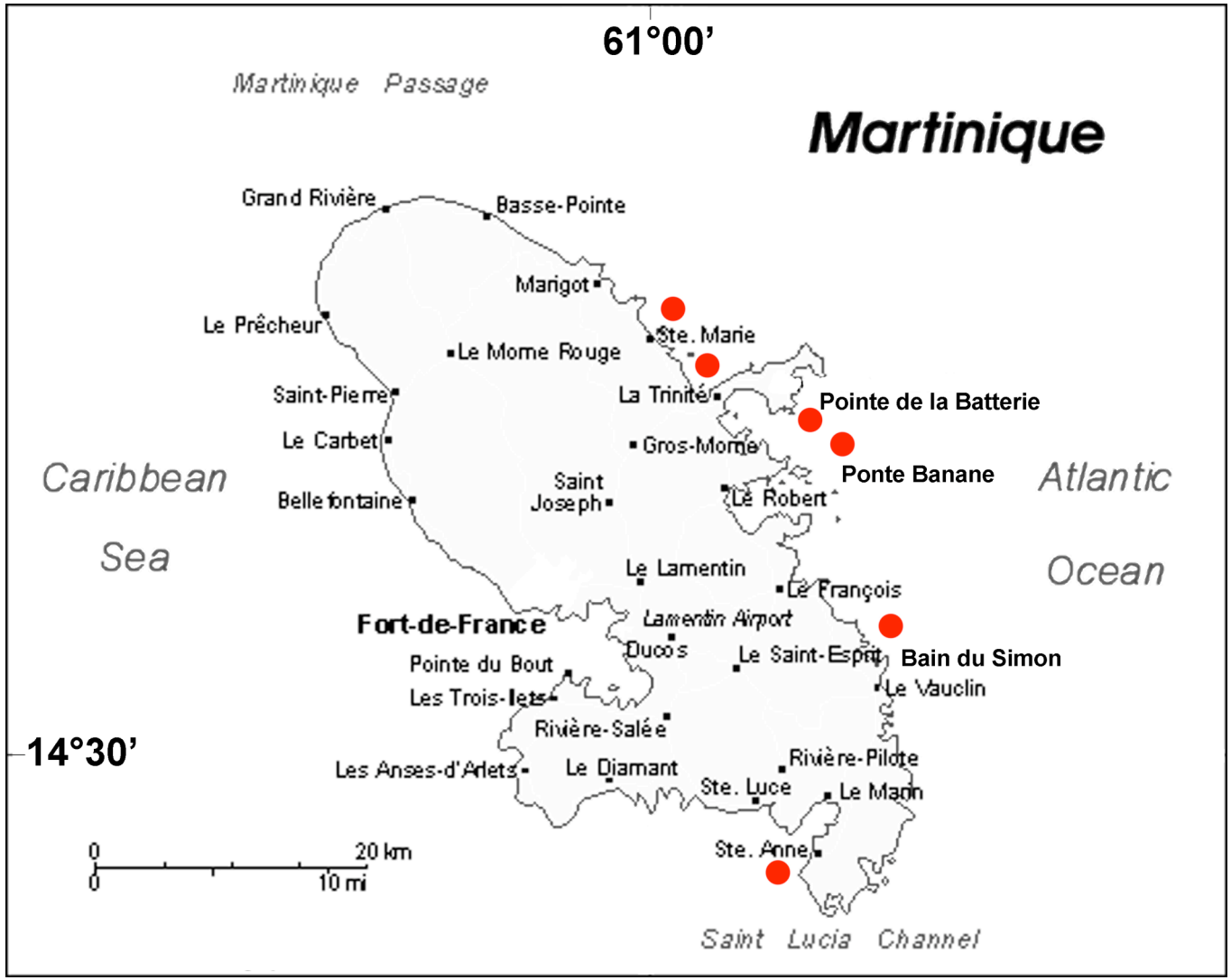

Bain-du-Simon
water level (m)
1.4
1
0.6
0.2
-0.2
-0.6
-1
-1.4
0
2
4
6
8
10
Time (hr)


Fond-Saint-Jacques
water level (m)
1.4
1
0.6
0.2
-0.2
-0.6
-1
-1.4
0
2
4
6
8
10
Time (hr)

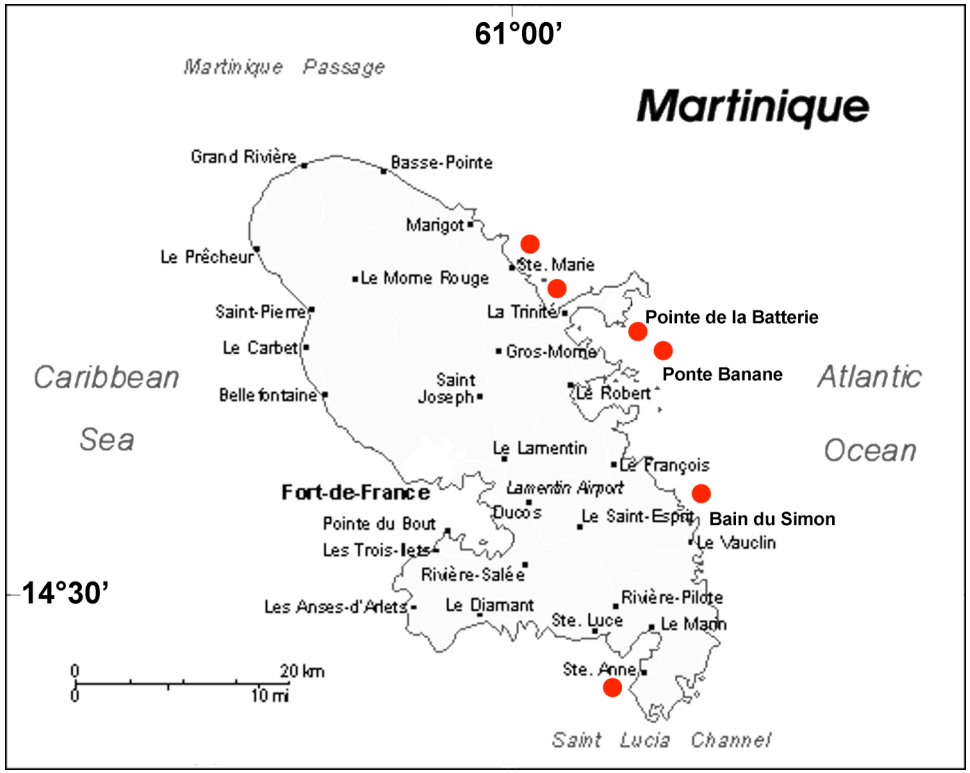

La-Trinité
water level (m)
1.4
1
0.6
0.2
-0.2
-0.6
-1
-1.4
0
2
4
6
8
10
Time (hr)


Pointe-Banane
water level (m)
1.4
1
0.6
0.2
-0.2
-0.6
-1
-1.4
0
2
4
6
8
10
Time (hr)

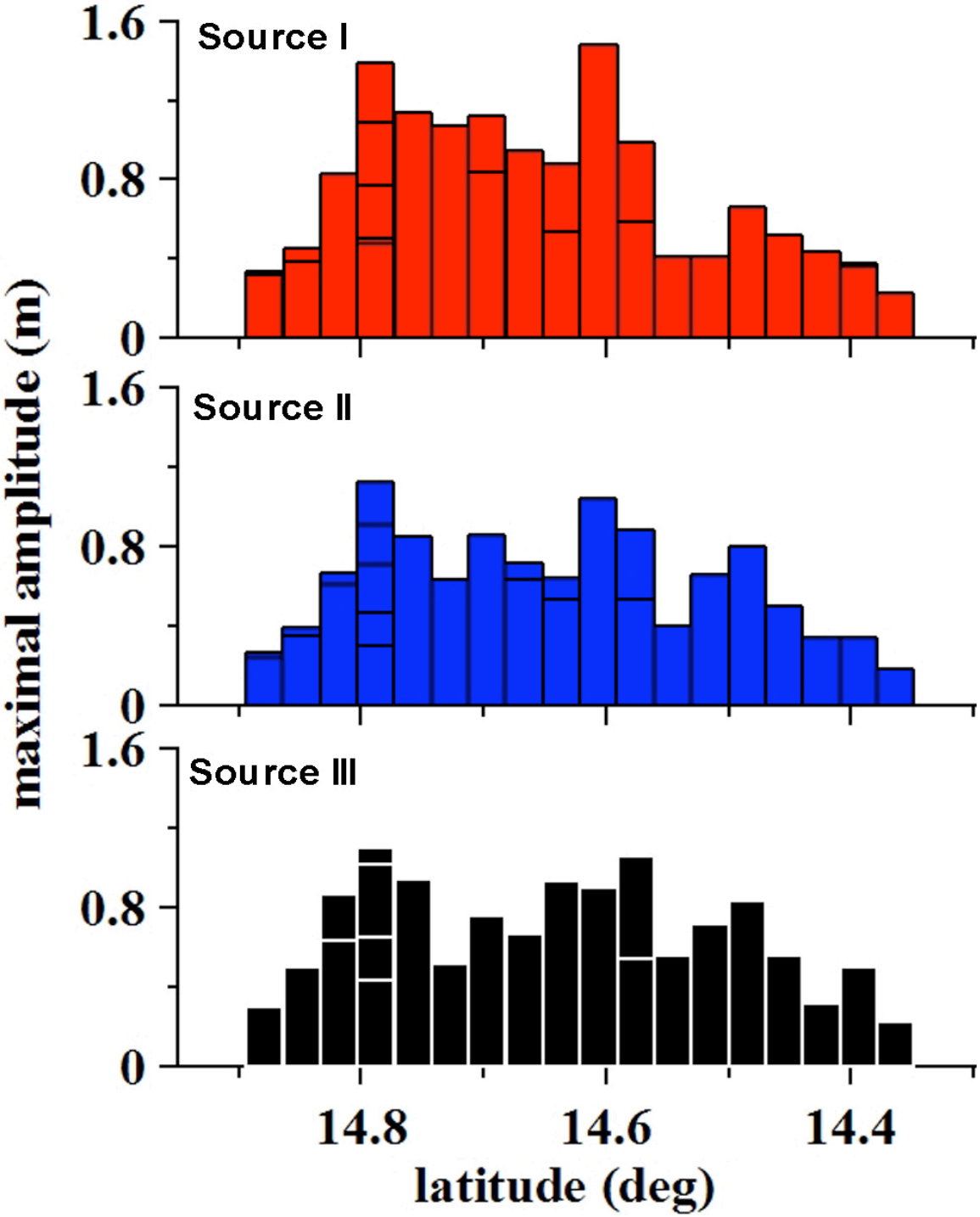

Pointe-de-la-Batterie
water level (m)
1.4
1
0.6
0.2
-0.2
-0.6
-1
-1.4
0
2
4
6
8
10
Time (hr)



Red points - locations where tsunami amplitude exceeds 1m



1.5 m in Bain du Simon;
1.4 m near Sainte Marie;
1.14 m in Pointe de la Batterie;
1.12 m in Sainte-Anne;
1 m in La Trinité and Pointe Banane.



Distribution of wave amplitude along eastern coast of Martinique

Conclusions:

The 1755 transatlantic tsunami is modeled by
using three similar seismic sources of different strike angles

The rupture parameters suggested by Gutscher et al. (2006) are used as input

**Tsunami energy is divided into two parts:
(Florida and the Bahamas) and Brazil.**

**Pointe des Chateaux, east of Guadeloupe,
amplitude - 2.17 m**

Bain du Simon, Martinique – 1.5 m

Observations: Guadeloupe 2-3 m, Martinique – 1.8 m