Tsunami modelling: on the use of databases (topo-bathymetry, land-use,…) for real events

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BRGM (French Geological Survey)
Risks et Risk Prevention Division
Coastal and Climate Change Risks / Seismic and Volcanic Risks

TANDEM AND DEFI LITTORAL: TSUNAMI SCHOOL
Bordeaux, April 25-29 2016

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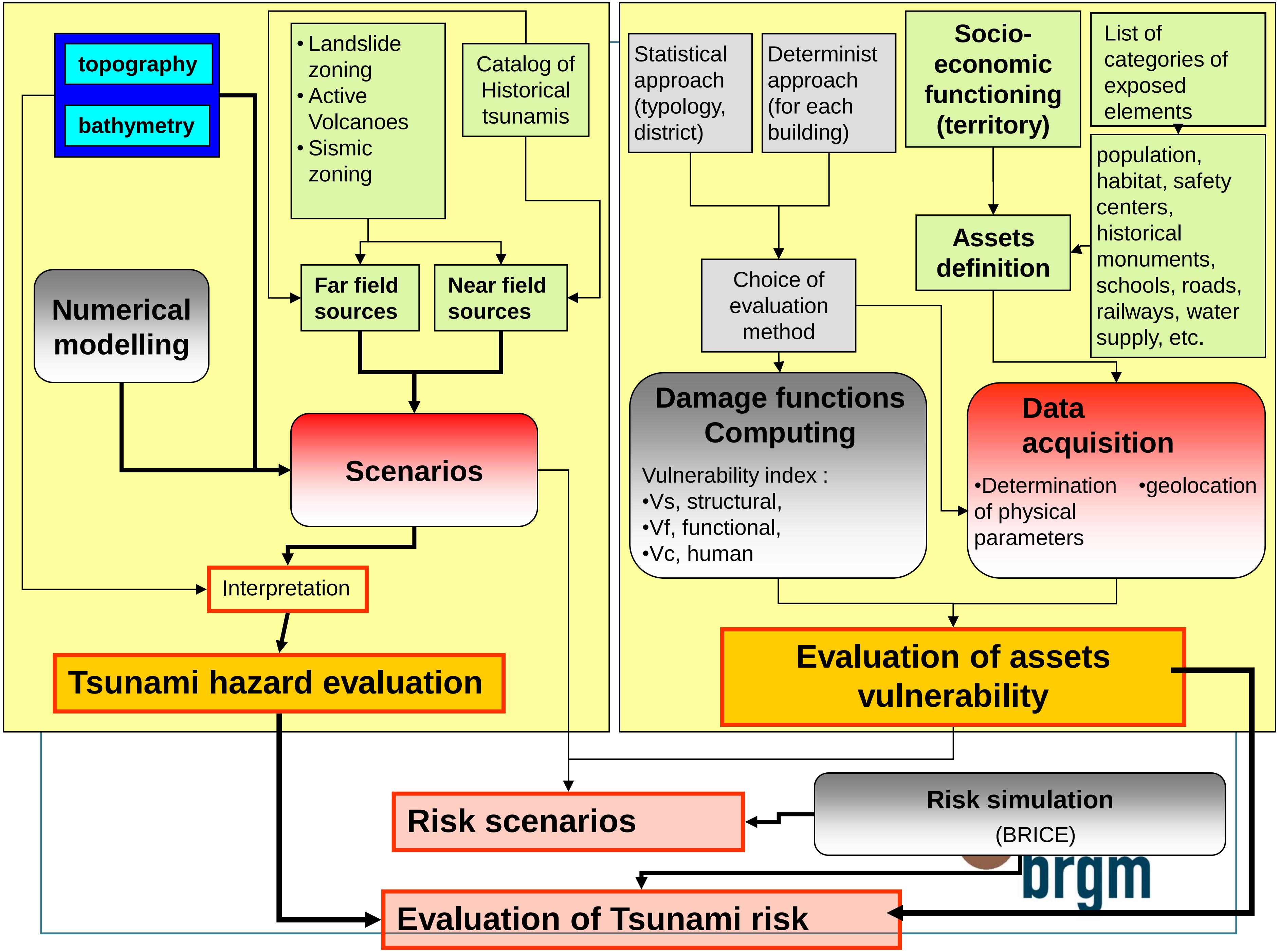
topography
bathymetry
• Landslide zoning
• Active Volcanoes
• Sismic zoning
Catalog of Historical tsunamis
Far field sources
Near field sources
Numerical modelling
Scenarios
Interpretation
Tsunami hazard evaluation
Statistical approach (typology, district)
Determinist approach (for each building)
Socio-economic functioning (territory)
List of categories of exposed elements
population, habitat, safety centers, historical monuments, schools, roads, railways, water supply, etc.
Assets definition
Choice of evaluation method
Damage functions Computing
Vulnerability index :
•Vs, structural,
•Vf, functional,
•Vc, human
Data acquisition
•Determination of physical parameters
•geolocation
Evaluation of assets vulnerability
Risk scenarios
Risk simulation
(BRICE)
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Evaluation of Tsunami risk

A- Tsunami Hazard Evaluation

1-Historical database

2-Water level measurements – Field observations

3- Topo-bathymetry – Building database

4- Land-use

B- Evaluation of assets vulnerability

1- Damages to buildings

2-Damages to people

1 – Catalogs of historical tsunamis

•Nationa
•Russia
•Genesi
Coasts (
•Italian (
•Caraïbe
(2002), .

Italian Catalogue, 67 events

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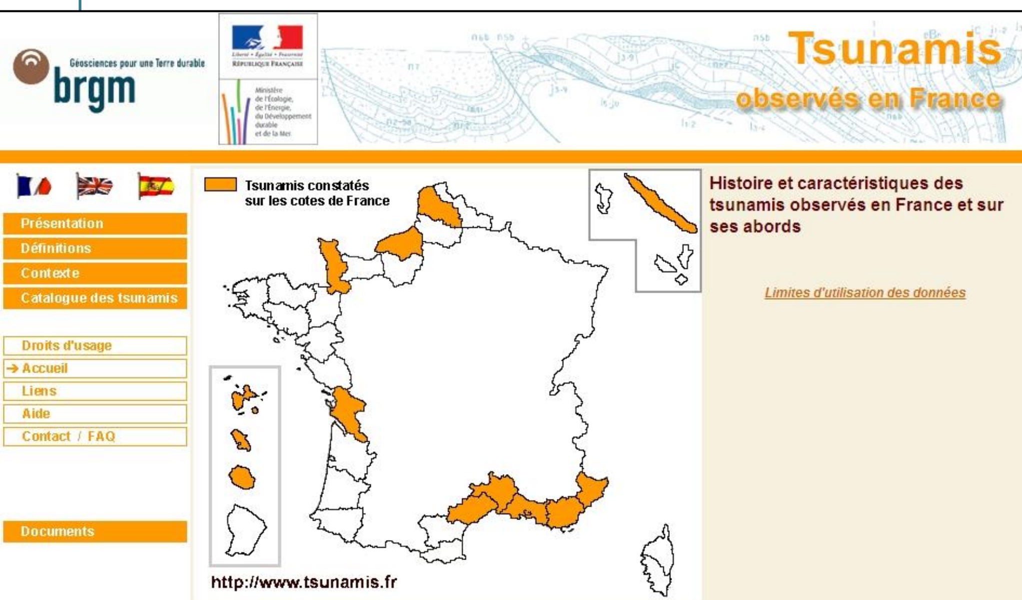
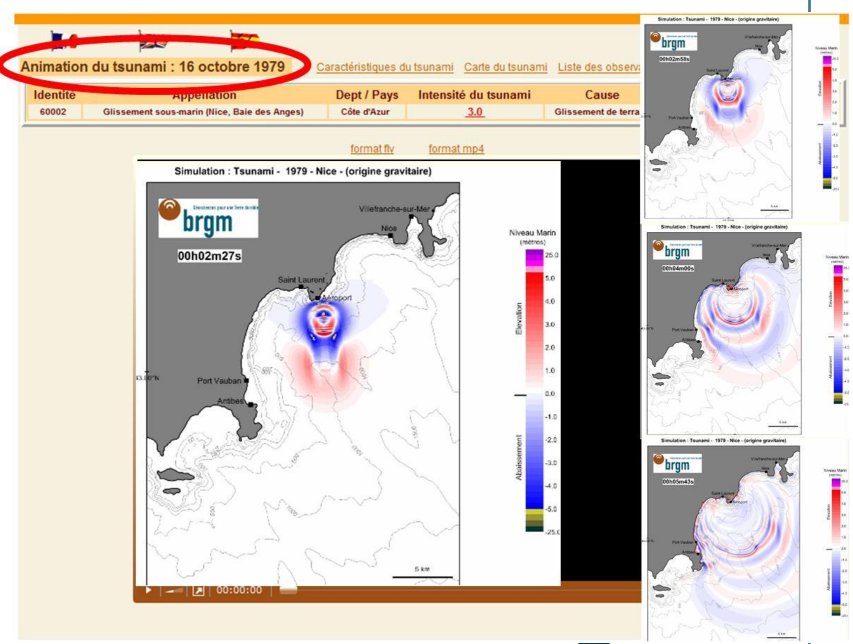
RIS/RIC

Tsunami database (www.tsunamis.fr)

- Base on **original documentary source** (books, scientific articles, historical articles, manuscripts, newspapers, travellers' accounts, chronicles, catalogues of earthquakes and meteorological data) **to prevent errors existing in most tsunami catalogues** (unit conversion problems, false tsunamis, etc…)
- **« True » tsunamis** (observations with confidence level, intensity maps, bibliography and "movies" from numerical simulations)
- list of **"False"** tsunamis (meteotsunami)





Lambert et Terrier 2011

Tsunami database : error example

> Tsunami of Lisbon 1755 :

- **Lander et al. 2002** give the distance of the sea's withdrawal as **"1.6 km"** for Martinique whereas the contemporary accounts evoke at the most a distance of **"200 pas"** (200 paces) equivalent to ~ **160 m at Trinité**

- For **O'Loughlin and Lander (2003**) a flood height of **"4.6m"** is envisaged at Martinique**,** whereas contemporary accounts only give a height of **"4 pieds" (4 feet)** equivalent to **1.30 m at Trinité**

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Présentation
Définitions
Contexte
→ Catalogue des tsunamis
Tsunamis régionaux
Faux tsunamis
Droits d'usage
Accueil
Liens
Aide
Contact / FAQ

Catalogue général des tsunamis par ordre chronologique

Sélection par bassins

Tous

Cliquez dans la colonne "Appellation" pour connaître les caractéristiques du tsunami

1

Date	Appellation	Région	Océan - Mer	Intensité
1 avril 2007	Séisme de Guadalcanal	Archipel des îles Salomon	Océan Pacifique	5
25 mars 1998	Séisme du nord Antarctique	Pacifique Sud	Océan Pacifique	Inconnue
16 octobre 1979	Glissement sous-marin (Nice, Baie des Anges)	Côte d'Azur	Mer Méditerranée	3
22 juin 1977	Séisme du sud de l'Archipel des Tonga	Pacifique Ouest	Océan Pacifique	Inconnue
7 septembre 1972	Séisme d'Oléron	Charente-Maritime	Océan Atlantique	2
23 février de 1887	Séisme de la Riviera italienne	Ligurie	Mer Méditerranée	3
22 avril 1882	Port de La Rochelle	Charente-Maritime	Océan Atlantique	3
9 juin 1875	Port de La Rochelle	Charente-Maritime	Océan Atlantique	3
28 mars 1875	Séisme des Nouvelles-Hébrides	Nouvelle-Calédonie, Vanuatu	Océan Pacifique	6
18 novembre 1867	Séisme des Iles Vierges (St-Thomas)	Antilles	Mer des Caraïbes	4
5 juin 1858	Normandie, Kent, Détroit de Calais	Manche	Manche	3
27 février de 1843	Port de Marseille	Provence	Mer Méditerranée	3
17 juillet 1841	Port de Sete	Languedoc	Mer Méditerranée	3
14 juillet 1841	Port de Marseille	Provence	Mer Méditerranée	2
8 juillet 1829	Port de Marseille	Provence	Mer Méditerranée	3
5 juillet 1817	Port de Marseille	Provence	Mer Méditerranée	Inconnue
27 juin 1812	Côte et port de Marseille	Provence	Mer Méditerranée	4
19 septembre 1810	Port de Boulogne-sur-Mer	Picardie	Manche	3
24 avril 1767	Atlantique, séisme du sud-ouest de la Barbade	Antilles (Martinique, Barbade)	Océan Atlantique	4
18 novembre 1755	Seisme de la Nouvelle Angleterre (Cape Ann)	Antilles	Océan Atlantique	4
1 novembre 1755	Séisme dit de "Lisbonne"	Antilles	Océan Atlantique	3
13 juillet 1725	Baie de Flamanville	Cotentin	Manche	2
29 juin 1725	Port de Marseille	Provence	Mer Méditerranée	2
20 juillet 1564	Glissement sous-marin	Côte d'Azur	Mer Méditerranée	2

Identité : **9710001**
Date du tsunami : **18 novembre 1867**
Appellation : **Séisme des Iles Vierges (St-Thomas) – Antilles**
Région de l'évènement : **Mer des Caraïbes**

1

Localité	Dept Pays	Vague			Retrait				Inondation				Runup		Intensité de l'onde		Longitude	Latitude	Date	Heure
		Nb	Haut.	Fiab.	Haut.	Fiab.	Dist.	Fiab.	Haut.	Fiab.	Prof.	Fiab.	Haut.	Fiab.	Int.	Fiab.	deg.dec	deg.dec		
ARROYO	Porto-Rico										40 m	C			3	B	-66,058	17,938		
BAIE DE YABUCOA (PORTO RICO)	Porto-Rico						136,5 m	C			136,5 m	C			4	B	-65,883	18,04		
BASSETERRE	Saint-Kitts														3	C	-62,717	17,3		
BASSE-TERRE	Guadeloupe	2			1 m	B	9 m	B	1 m	B			2 m	C	3	C	-61,73	16		
CHARLOTTE AMALIE (ST-THOMAS)	Saint-Thomas	3	7,36 m	B			96 m	C	2,56 m	B	80 m	B			4	B	-64,93	18,34		à 15 h 20 min
CHRISTIANSTED (ST-CROIX)	Saint-Croix														4	B	-64,7	17,74		
DESHAIES	Guadeloupe				4 m	C									3	B	-61,78	16,32		
FOND-CURE (TERRE-DE-HAUT)	Guadeloupe														3	B	-61,58	15,86		
FREDERIKSTED (ST-CROIX)	Saint-Croix	3	8,8 m	B											4	B	-64,88	17,71		
GOUYAVE	Grenada												6,4 m	C	4	C	-61,733	12,167		
ILE DE BEQUIA (PORT ELIZABETH)	Grenadines	3							1,92 m	C					3	C	-61,233	13,017		
ILE DE SAINT-MARTIN	Guadeloupe														3	C	-63,08	18,07		
ILE DE SAINT-VINCENT (KINGSTOWN)	Saint-Vincent														2	C	-61,217	13,133		
PETER ISLAND (TORTOLA)	Tortola														4	C	-64,58	18,35		
POINTE-A-PITRE	Guadeloupe				0,4 m	C									2	C	-61,53	16,25		
ROAD TOWN (TORTOLA)	Tortola								1,44 m	B					4	B	-64,62	18,42		
SAINT-BARTHELEMY	Guadeloupe														3	C	-62,85	17,9		
SAINTE-ROSE	Guadeloupe	3			4 m	C	150 m	C							3	B	-61,7	16,33		à 15 h 18 min
SAINT-GEORGE'S	Grenada	6			1,44 m	B									2	C	-61,75	12,05		
SAINT-JOHN'S	Antigua								2,88 m	C					3	C	-61,85	17,117		
WATER ISLAND	Saint-																			

ibliographie | Caractéristiques du tsunami | Carte du tsunami | Liste des observations | Page d'accu

Identité : **9710001**
Date du tsunami : **18 novembre 1867**
Appellation : **Séisme des Iles Vierges (St-Thomas) – Antilles**
Région de l'évènement : **Mer des Caraïbes**

1

Auteur	Article	Référence	Tomaison, Série	Lieu d'édition	Date de publication
REID. H-F, TABER. S	THE VIRGIN ISLANDS EARTHQUAKES OF 1867-1868	BULLETIN OF THE SEISMOLOGICAL SOCIETY OF AMERICA	T 10		1920
DEVILLE. CH	SUR LE TREMBLEMENT DE TERRE DU 18 NOVEMBRE 1867 AUX ANTILLES	C.R. ACADEMIE DES SCIENCES DE PARIS	T 65	PARIS	1867
LE VERRIER	COMMUNICATION D'UNE LETTRE DE M. GAILLARD, DE POINTE-A-PITRE	C.R. ACADEMIE DES SCIENCES DE PARIS	T 65	PARIS	1867
RAUPACH	LISTE DES SECOUSSES ET DES BRUITS SOURDS QUI SUIVIRENT LE TERRIBLE TREMBLEMENT DE TERRE SURVENU A L'ILE SAINT-THOMAS, LE 18 NOVEMBRE 1867	C.R. ACADEMIE DES SCIENCES DE PARIS	T 66	PARIS	1868
PERREY. A	NOTE SUR LES TREMBLEMENTS DE TERRE RESSENTIS EN 1866 ET 1867, AVEC SUPPLEMENT POUR LES ANNEES 1843 A 1865	MEMOIRES COURONNES ET AUTRES MEMOIRES DE L'ACADEMIE ROYALE DES SCIENCES, DES LETTRES ET DES BEAUX-ARTS DE Belgique	T 21	BRUXELLES	1870
ZAHIBO. N, PELINOVSKY. A, YALCINER. A, KURKIN. A, KOSELKOV. A, ZAITSEV. A	THE 1867 VIRGIN ISLAND TSUNAMI	NATURAL HAZARDS AND EARTH SCIENCES	VOL 3		2003
	[EXTRAORDINARY EFFECTS OF AN EARTHQUAKE : 1867, NOVEMBER, 18TH]	SCIENTIFIC (THE) AMERICAN			28 décembre 1867

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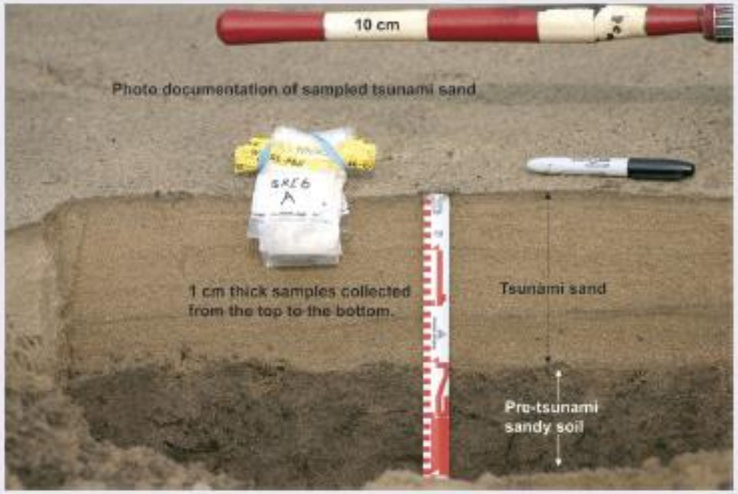
1- Paleo-tsunami database (NOAA)

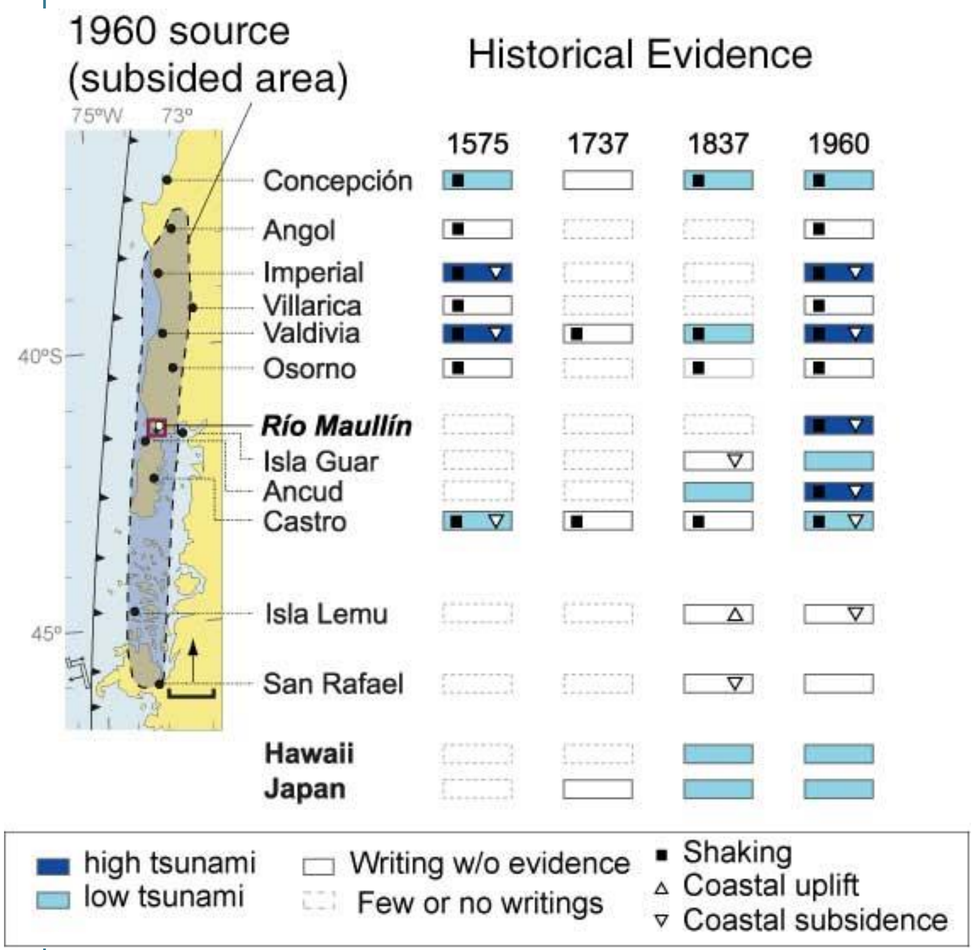
> **Tsunamites: 1KY to 100 KY. Qualitative information (intensity and localisation)**

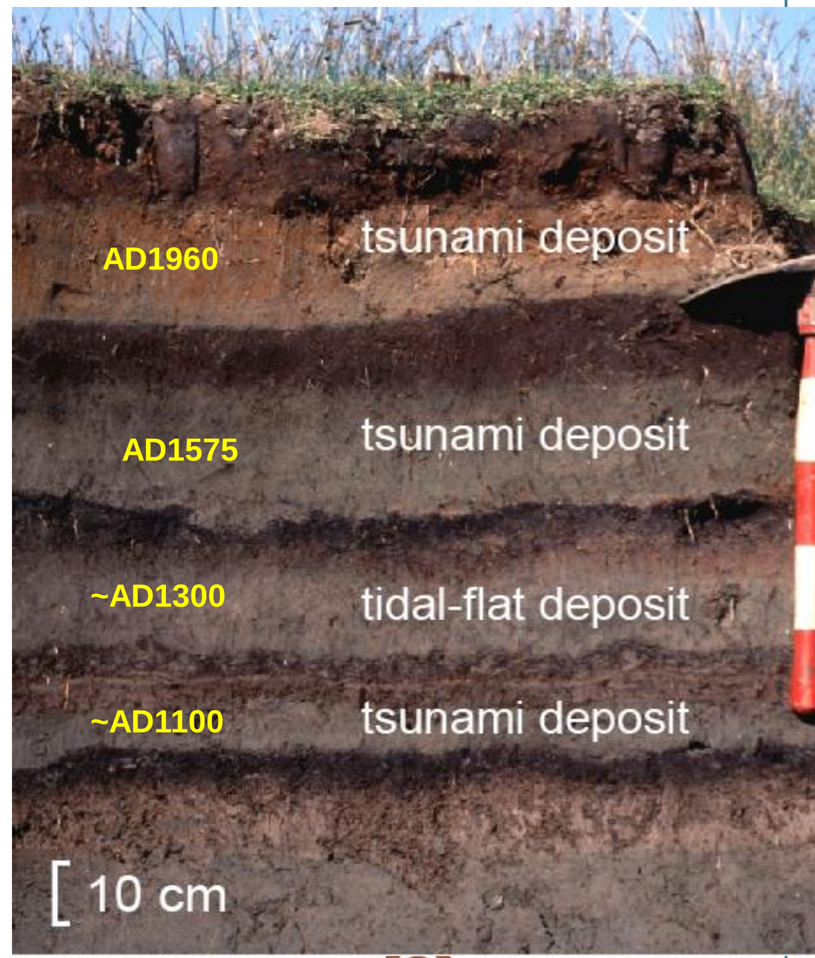


Exemple de dépôt de sable lié au tsunami du 26 décembre 2004 *(Sri Lanka, © USGS)*

South-Central Chile

Cisternas et al. (2005 Nature)





Giant (M~9.5) earthquakes ~300 yr interval
NOT ~ 100 yr as inferred from historic data

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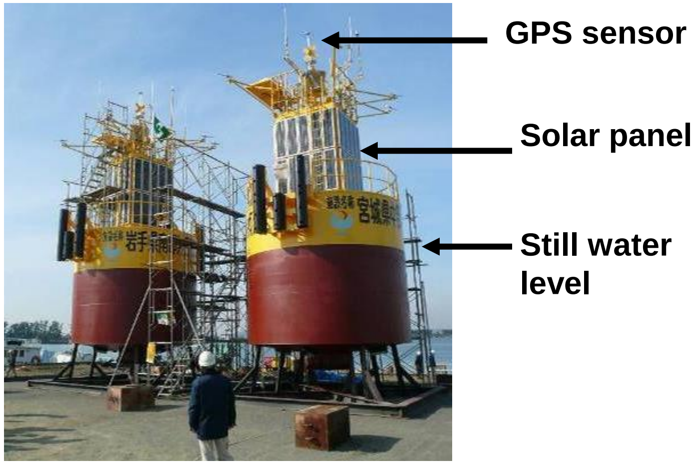
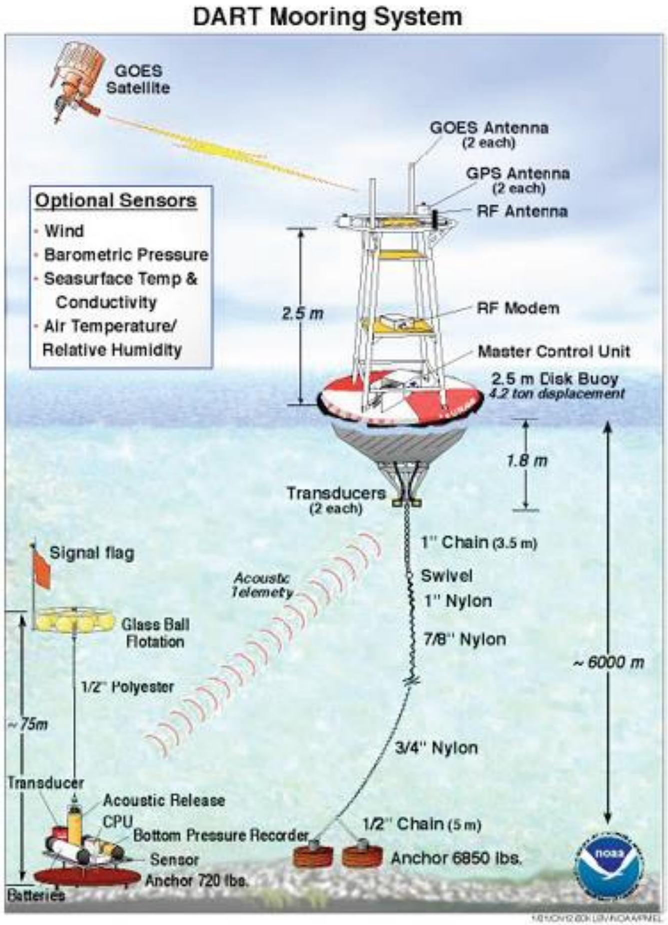
2 – Water level

> **Tide gauges, tsunamimeters, GPS buoy : mesure de la <u>hauteur et de la période des tsunamis</u> couvrant environ <u>les 50 dernières années</u>. Ils se font généralement aux niveaux des ports (marégraphes). Les données en haute mer (tsunamimètres) sont rares et concernent essentiellement les zones où un système d'alerte. La fréquence d'acquisition des marégraphes n'est pas adaptée à la quantification des tsunamis champ proche (améliorations en cours)**

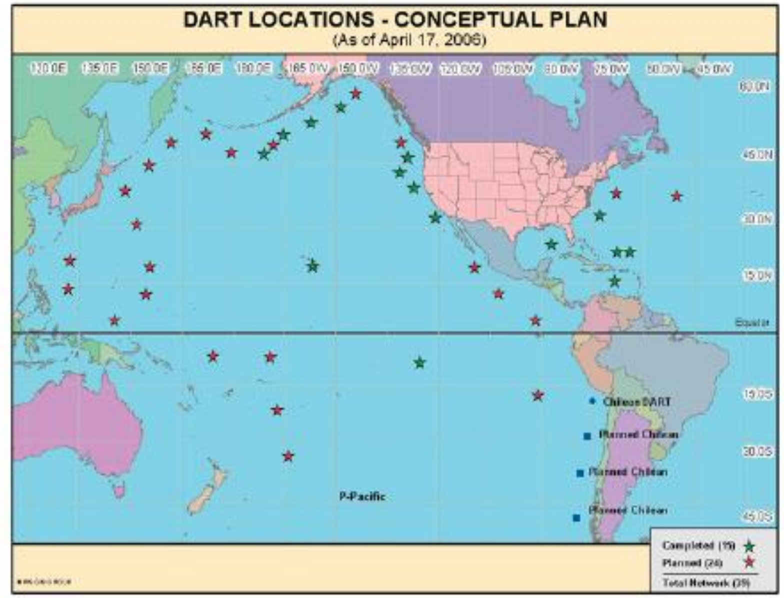


Exemple de tsunamimètre (*tsunameter*) du réseau DART (©*NOAA*)

Tsunameters: DART buoys



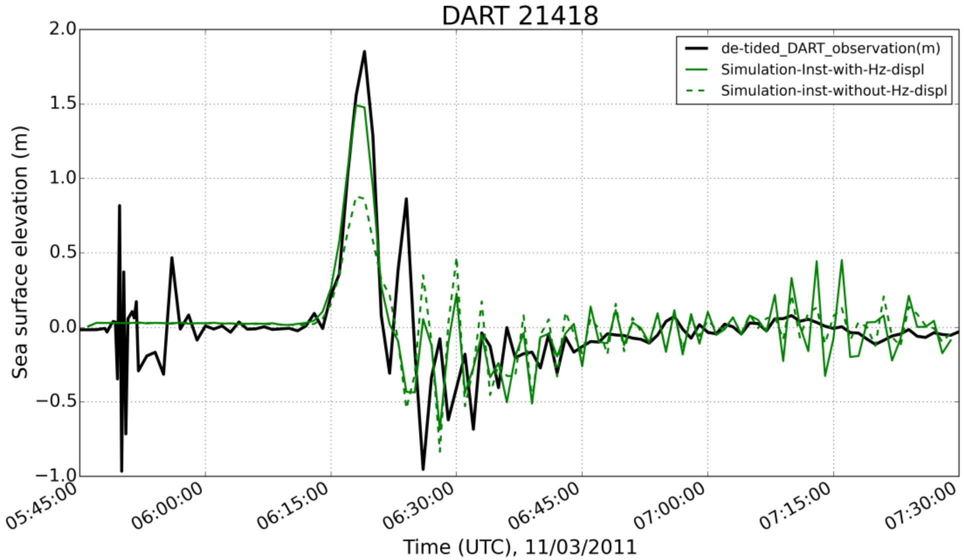
(www.noaa.gov)

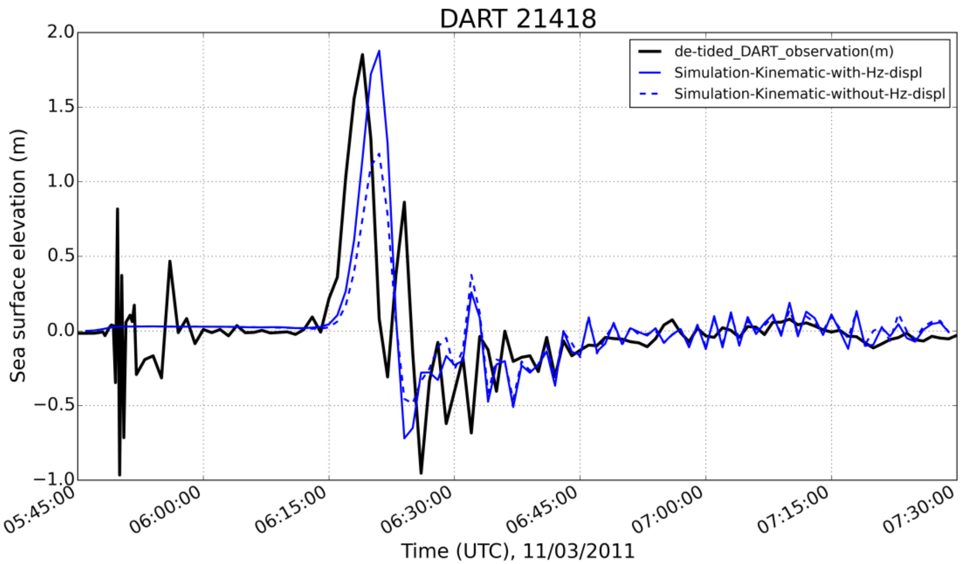


- Covers most part of the Pacific
- Observe tsunami before it arrives to coastline
- Indirect sea-height measurement through pressure

Results obtained on Rank 0 (600m resolution)

> **Preliminary comparison with Tsunami dart 21418 (about 800km off Japan coasts)**





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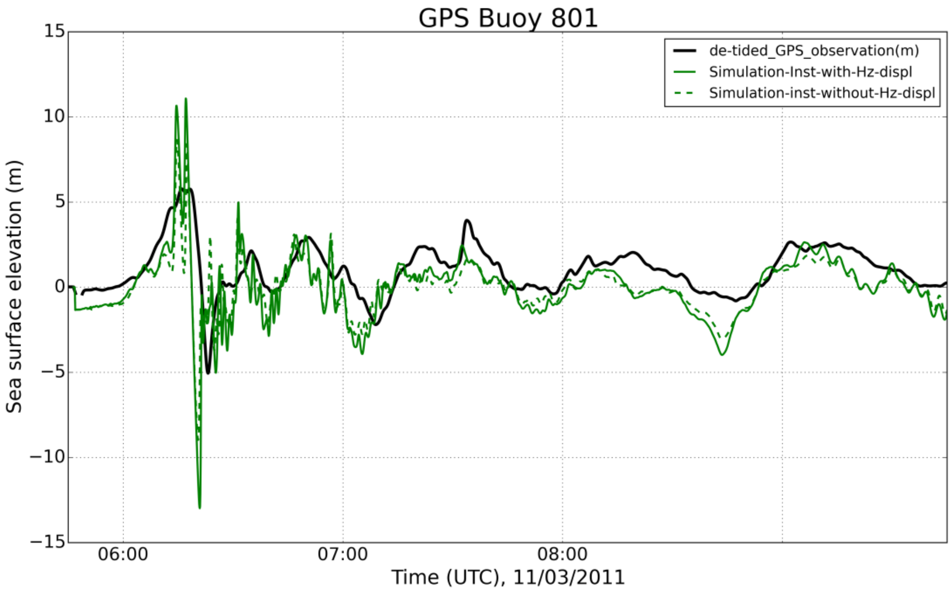
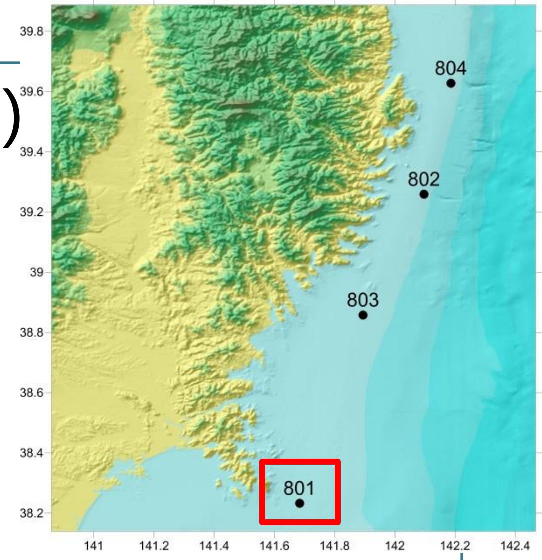
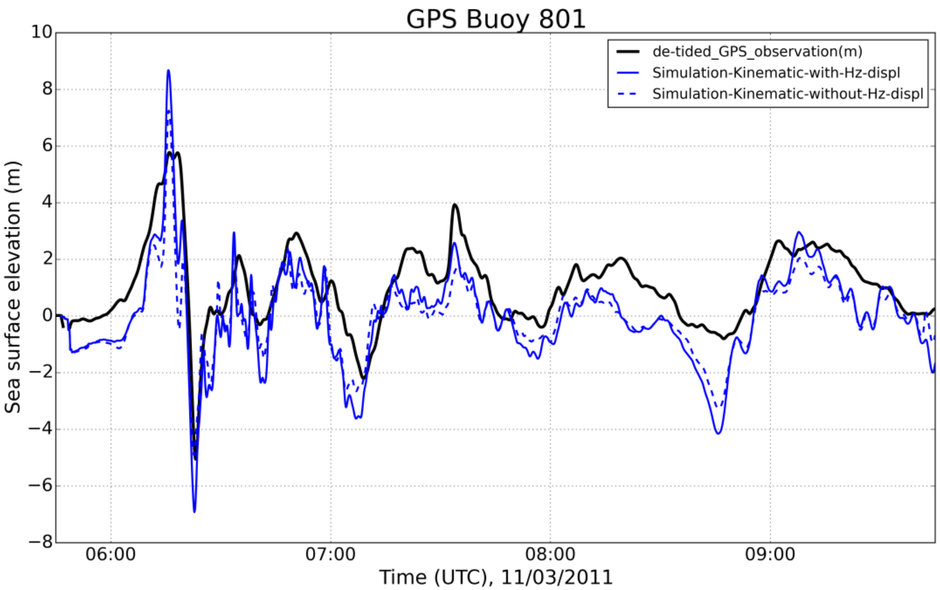
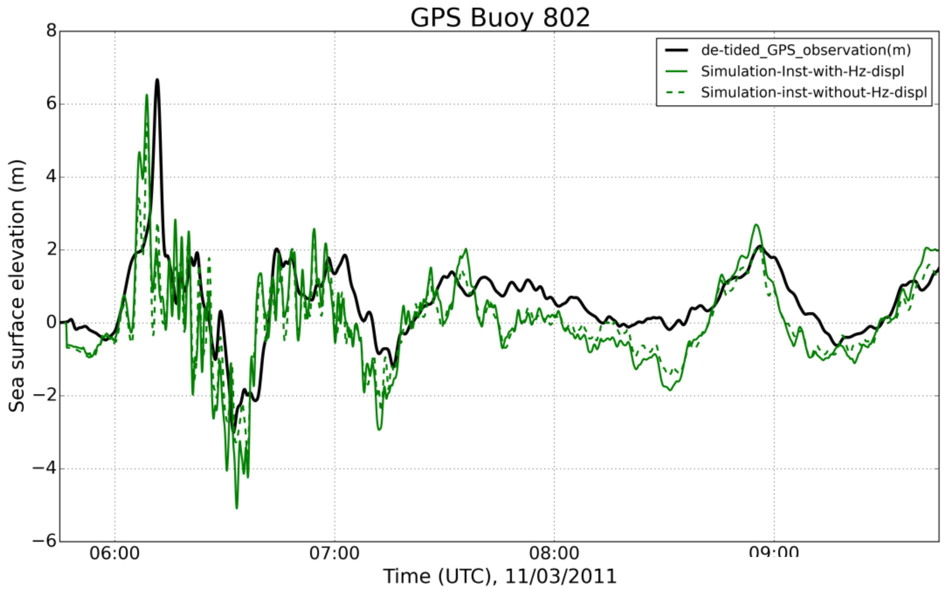
Results obtained on Rank 1 (200m resolution)

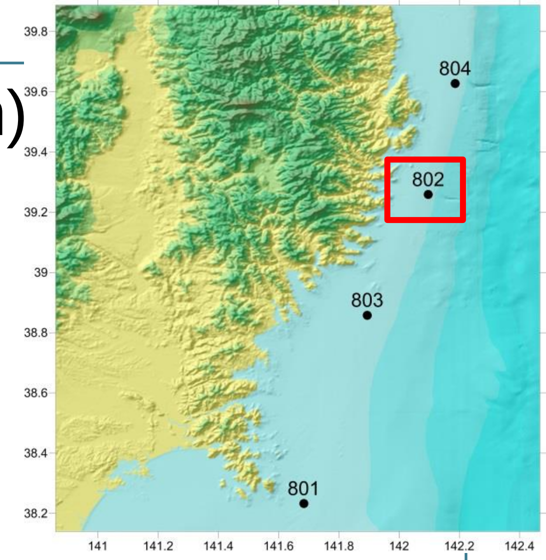


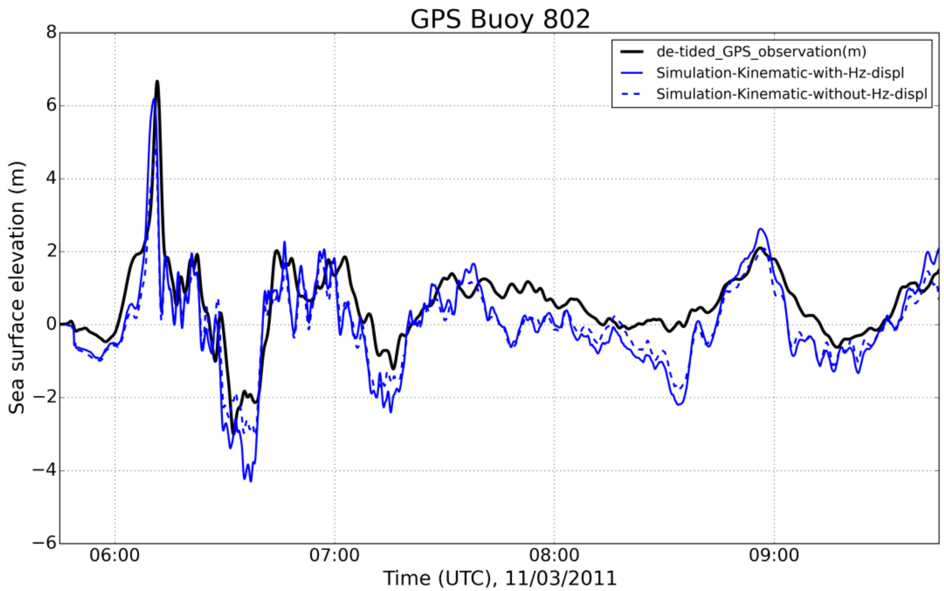




Results obtained on Rank 1 (200m resolution)







3 - Sources de données (caractérisation des tsunamis)

Marégraphes

http://www.ioc-sealevelmonitoring.org/

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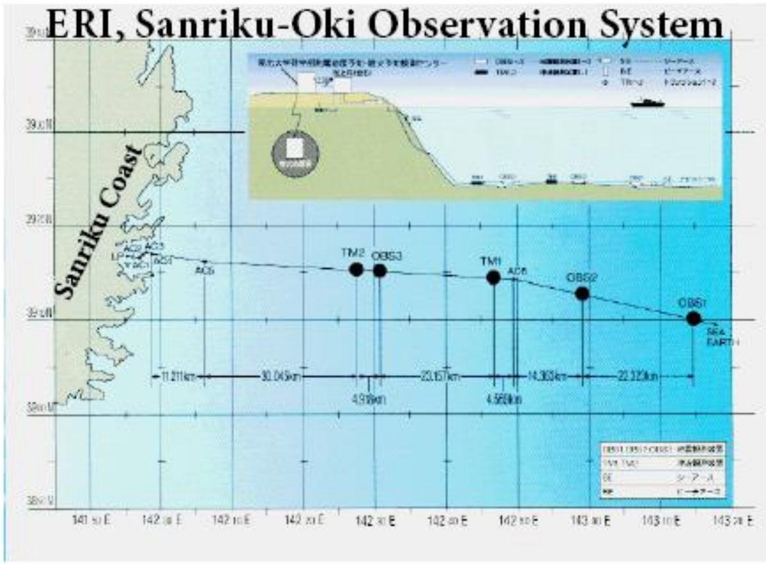
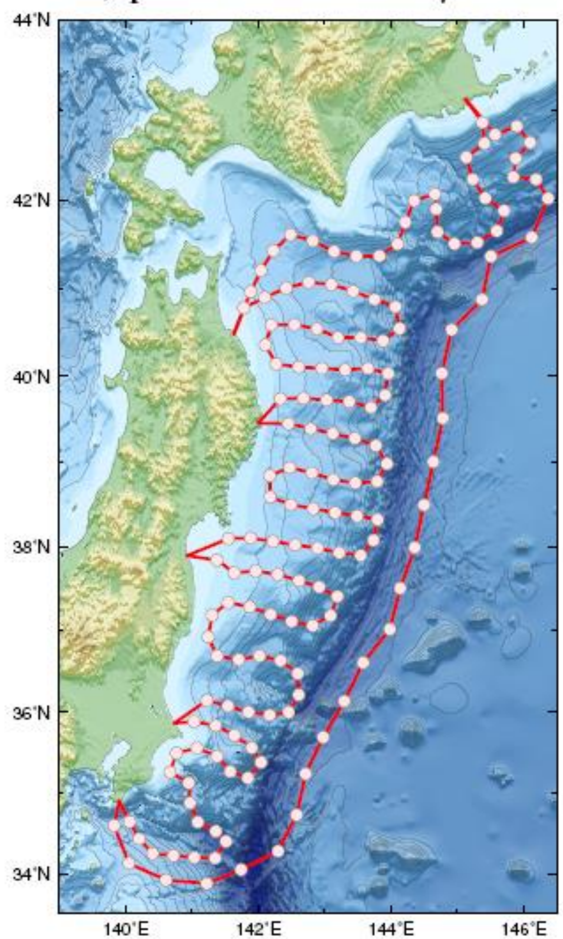
Cabled OBPG (Ocean Bottom Pressure Gauge)



- Measure tsunami height through pressure
- Directly cabled to land
- Can transmit high-sampling realtime data
- May include “seismic” station too
- Very a few stations, but increasing

New Japan Trench Network by ~2015



(Uehira, et al., 2012)

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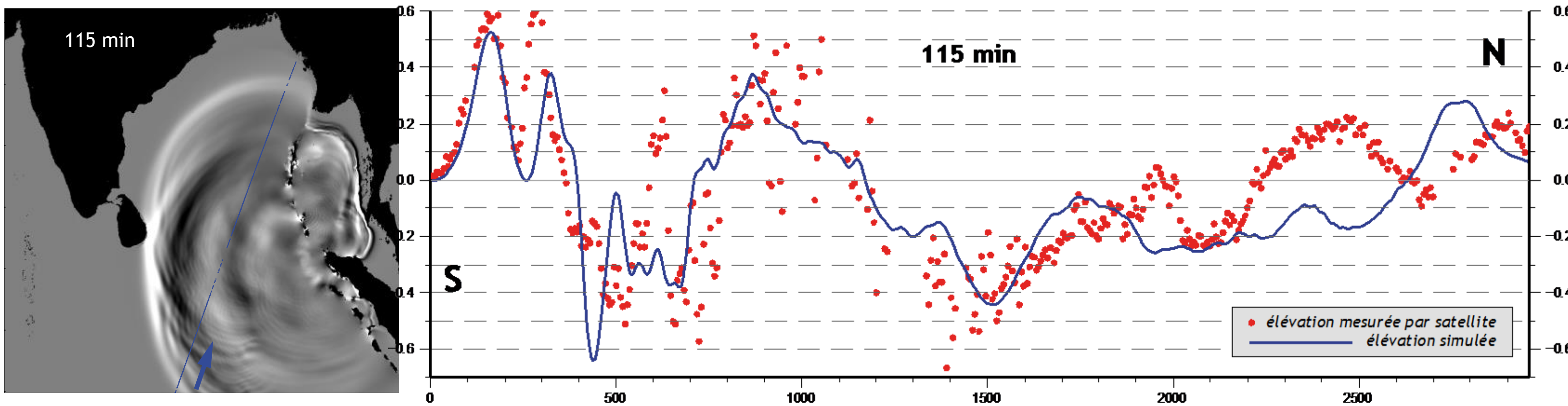
2 - Satellite

> **Observations spatiales Jason et Topex-Poséidon altimeter : dans certaines configurations de mesurer la hauteur et la longueur d'onde des tsunamis en haute mer**



SUMATRA 2004

2- Field observations

> **Campagnes de terrain post-évènement :** déplacement sur les lieux ayant été le plus touchés dans le but de mesurer le **run-up et la limite d'inondation**, recueillir des témoignages (nombre de vagues, hauteurs,…) et constater les **dégâts occasionnés**. Ces données sont exploitées pour le calage des modélisations des tsunamis et l'établissement d'échelles d'endommagements utilisées pour l'estimation de la vulnérabilité.

Exemple de dégâts liés au tsunami du 26 décembre 2004 au Sri Lanka

(GSMB, BRGM)

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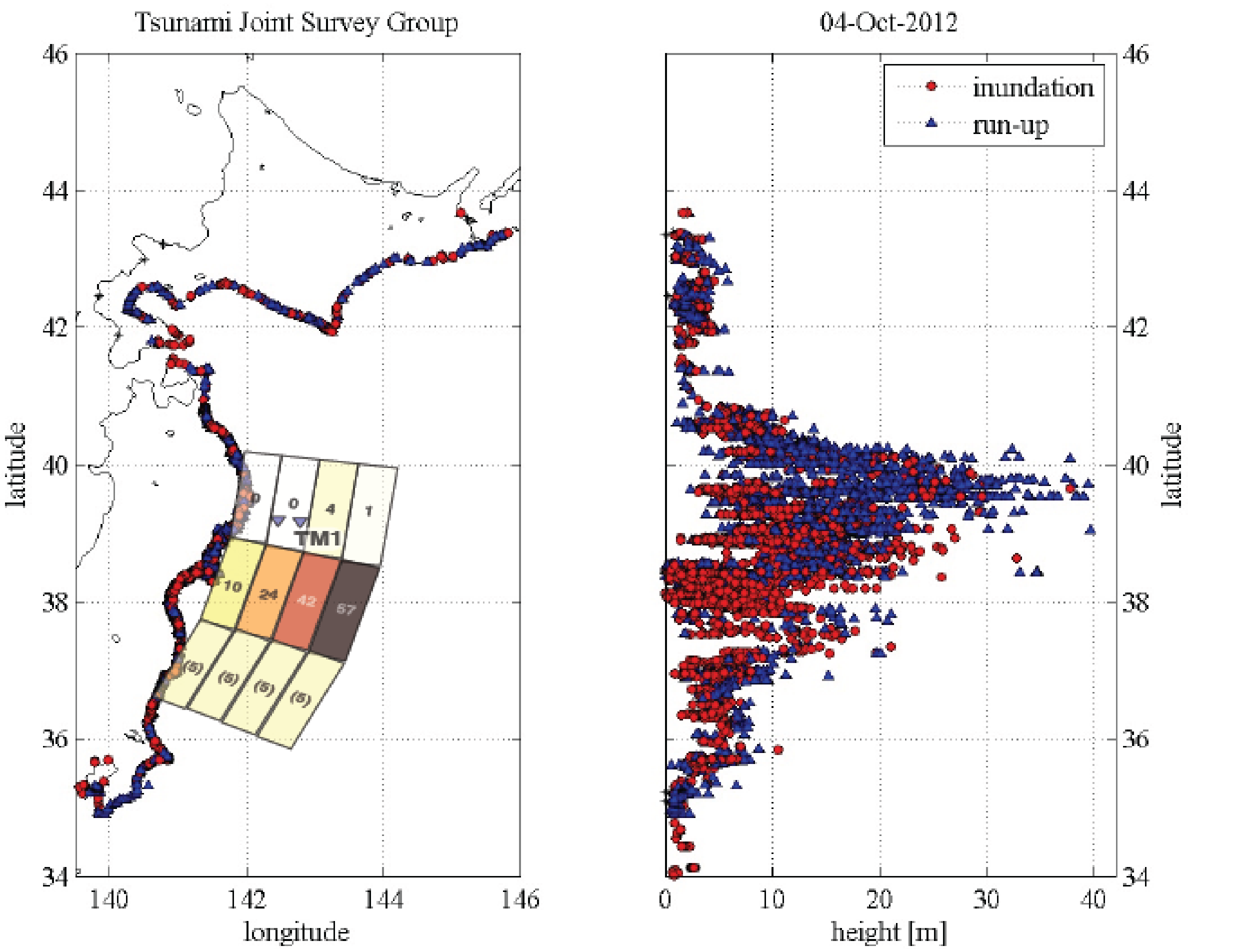
2- Field observations : Japan 2011



(Field data by tsunami joint survey group, 2012)

- **Inundation & run-up height shift to northern part than slip**

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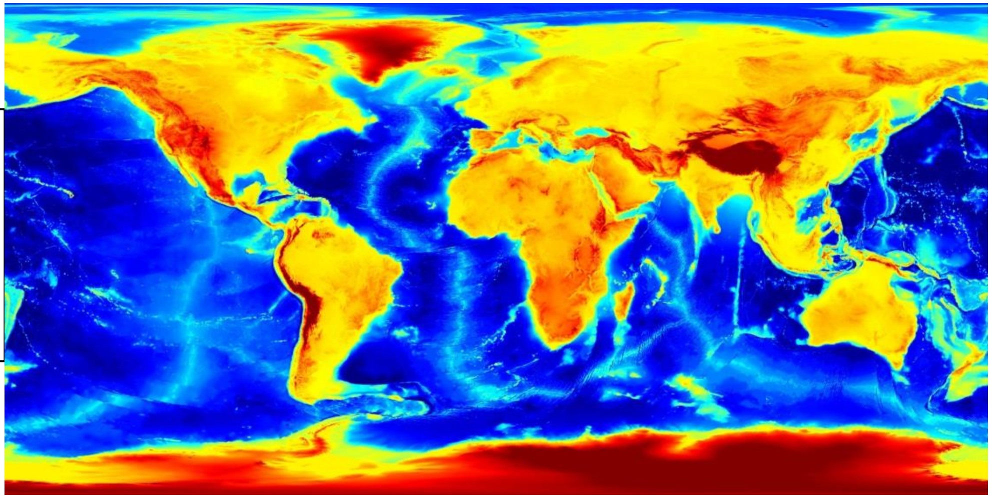
3- Topo-bathymetry

> Bases de données mondiales



Bathymétrie

- **GEBCO 2014** ~900 m
- **ETOPO** : ~ 1800m

Topographie

- **SRTM** : 90 (30) m x 90 (30m) m

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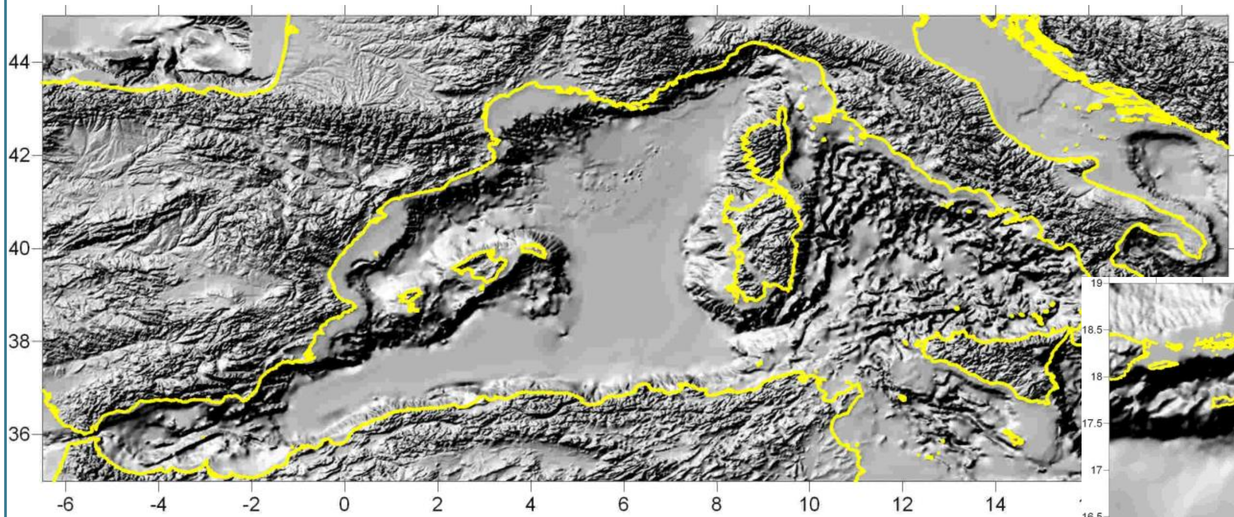
3- **Topo-bathymetry**

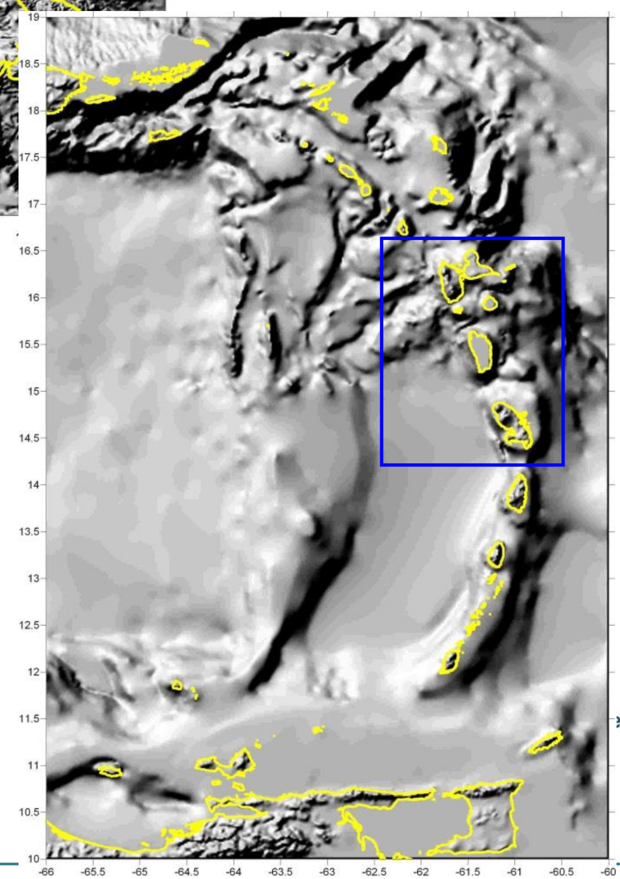
> **Bases de données mondiales (accès libre)**

GEBCO :
ETOPO 1:



Topographie : SRTM (~90m)

Trait de côte: GHSS, NGA (-> 50 à 200m)



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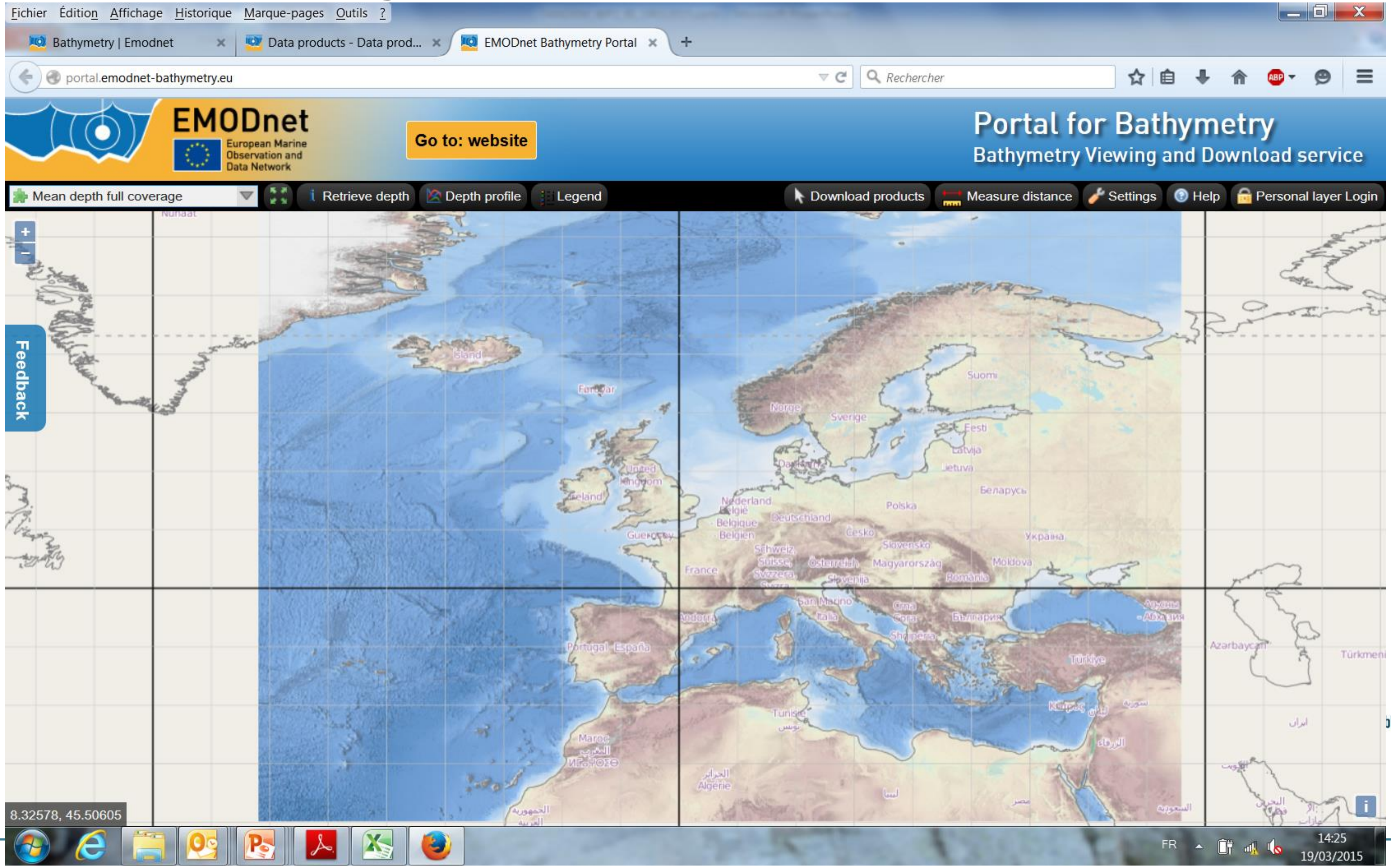
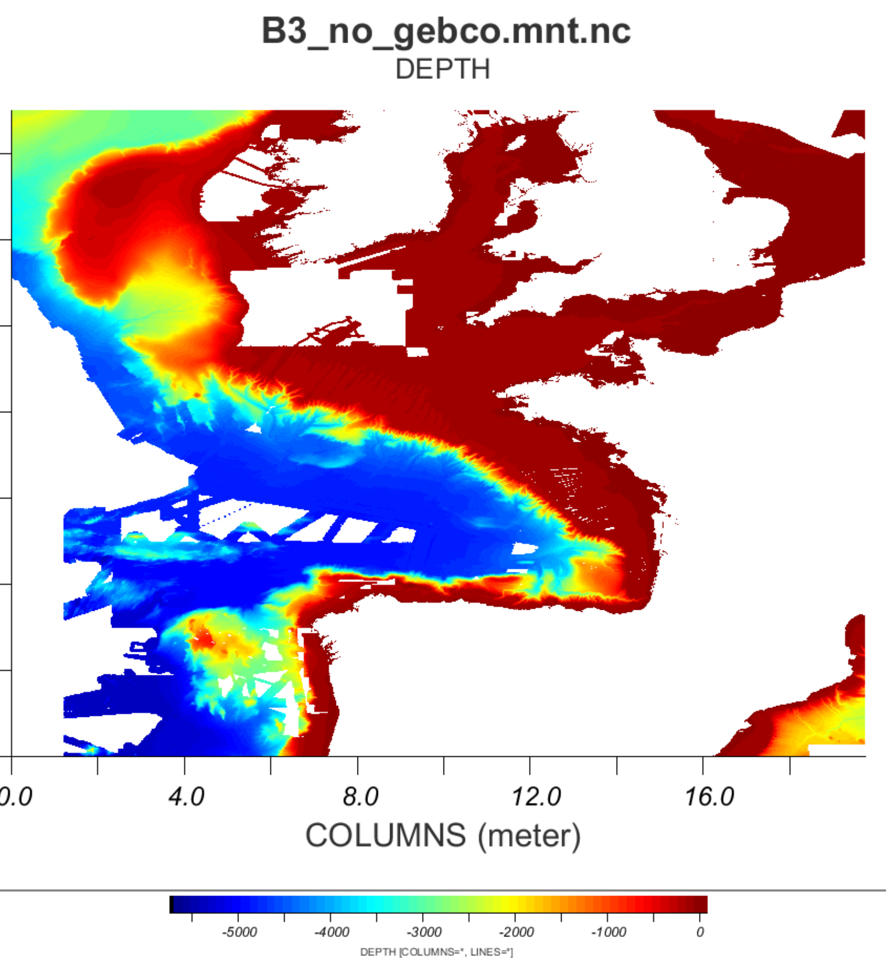
Bathymetry : Emodnet

- **Résolution spatiale ~ 230m x 230m (février 2015)!!!**
- **Levés bathy + GEBCO 2014**

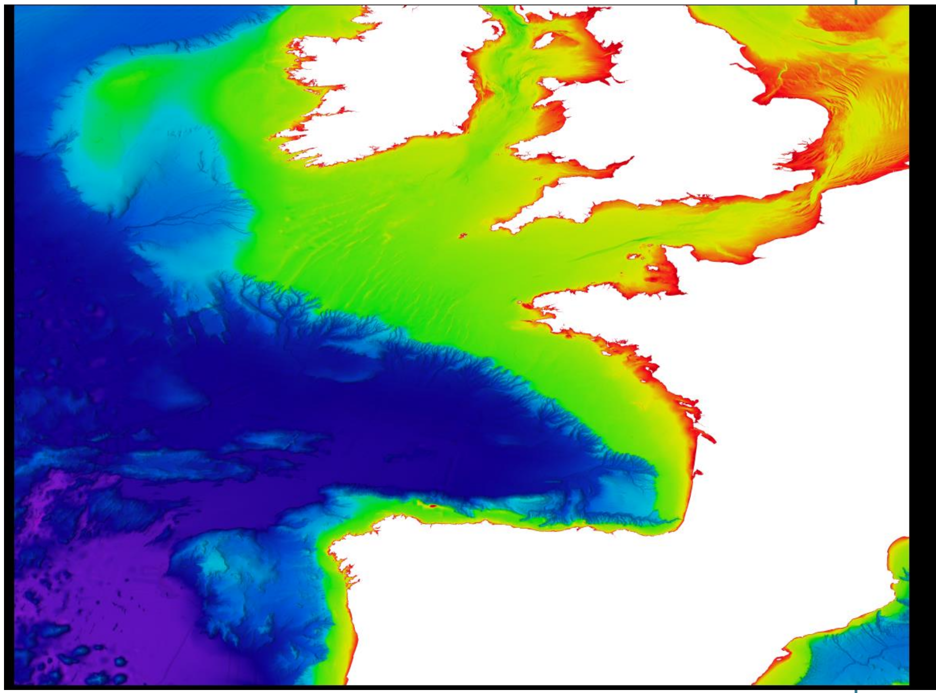


3 - Bathymétrie : Emodnet

> Produit sans Gebco



Avec fusion Gebco 2014



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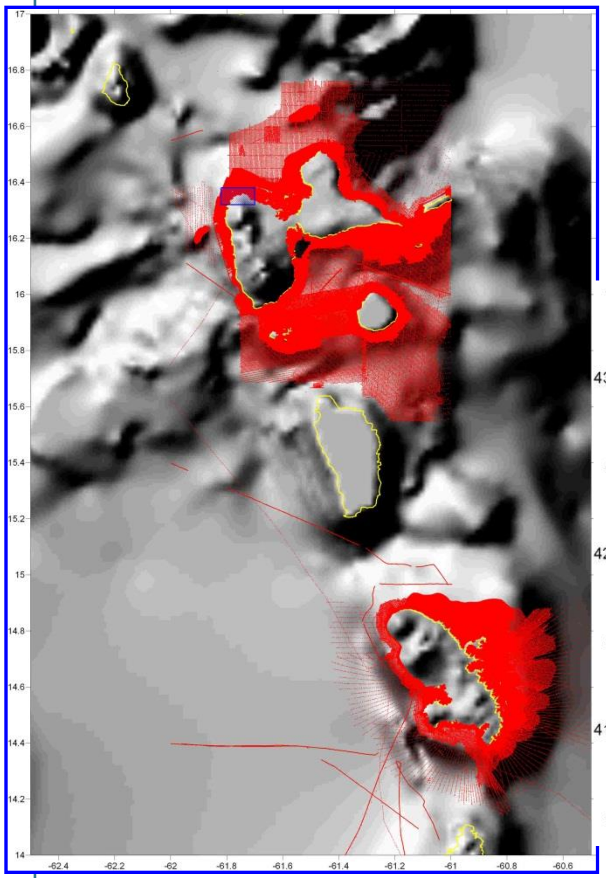
3- Topo-Bathymetry

> Base de données nationales

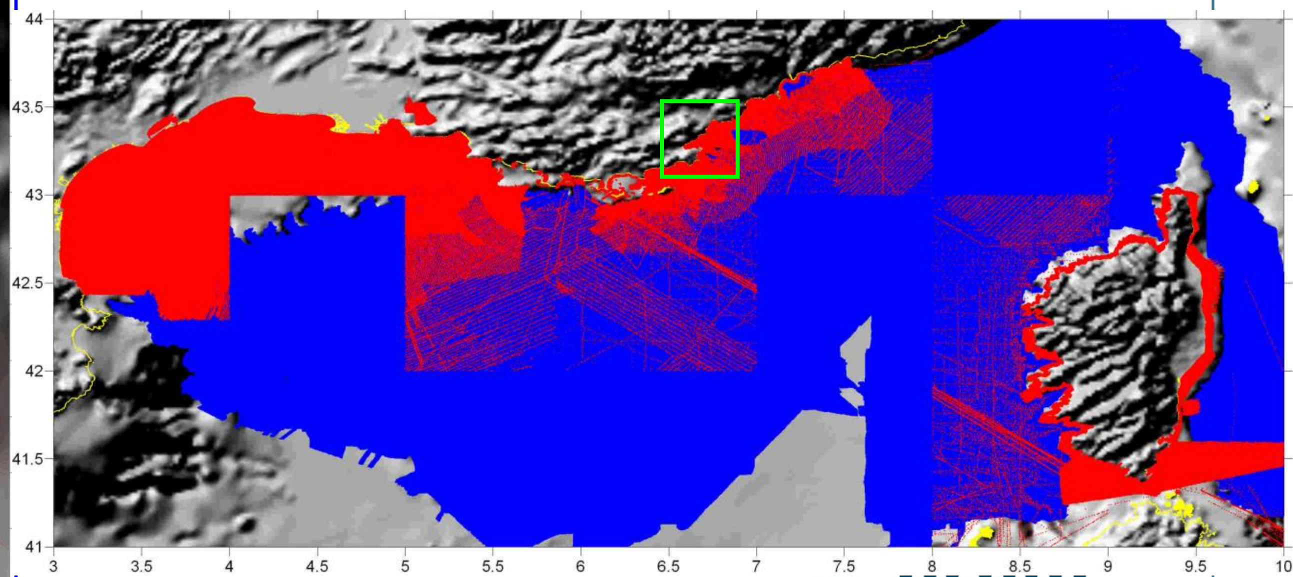
SHOM : Dalles + trait de côte

Histolitt

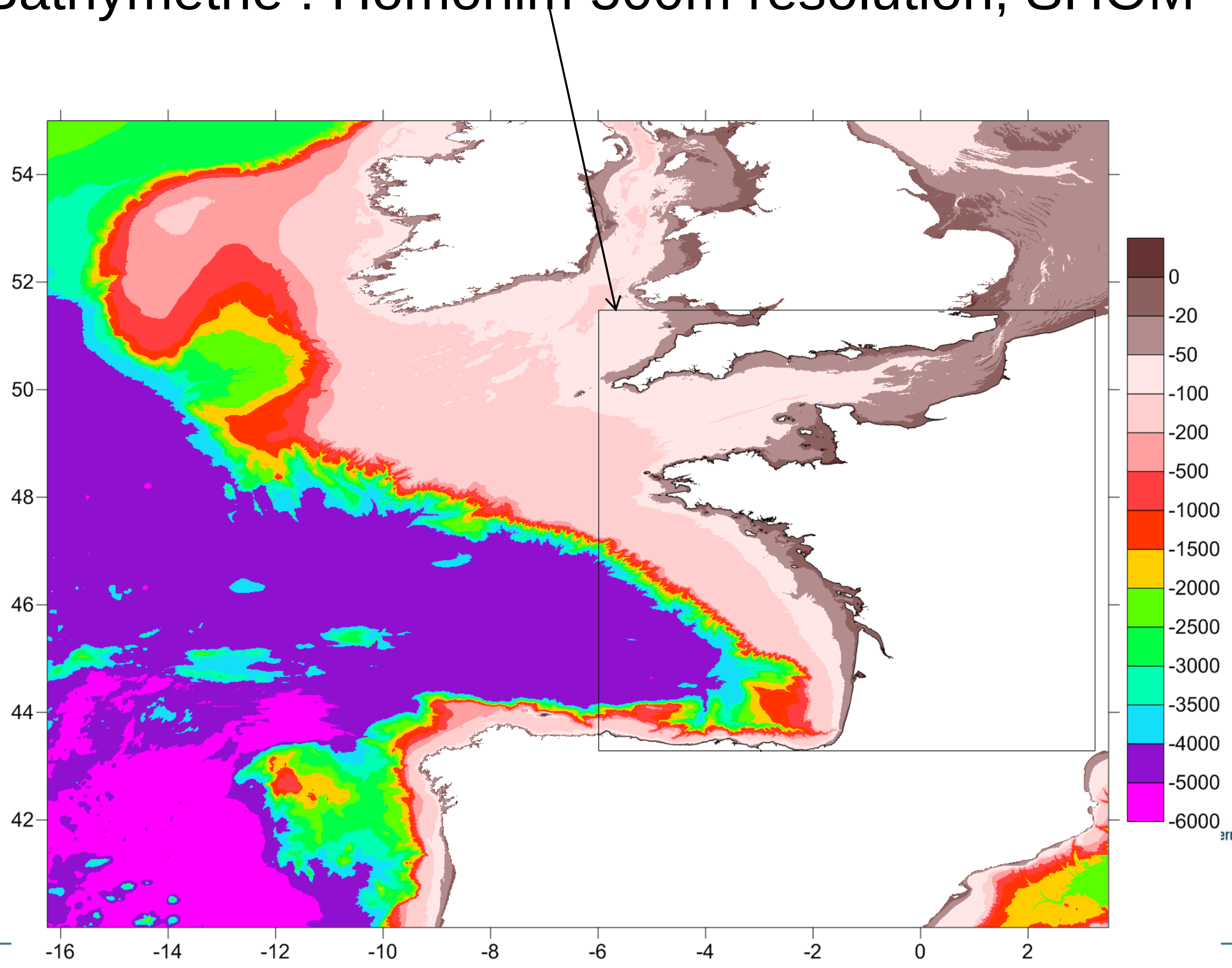
Résolution la plus haute ~ 25 m



IGN : MNT 50m



Bathymétrie : Homonim 500m résolution, SHOM



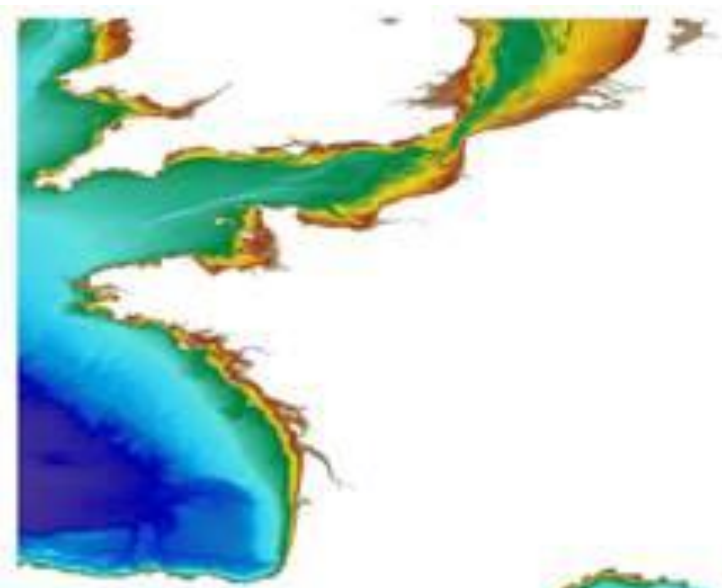
erre durable

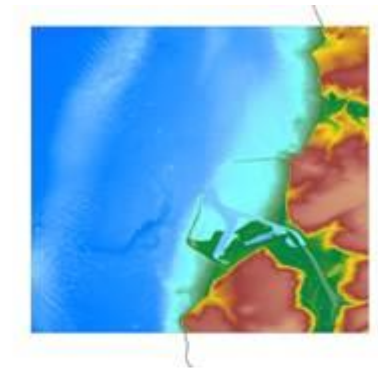
3-Topo-Bathymétrie

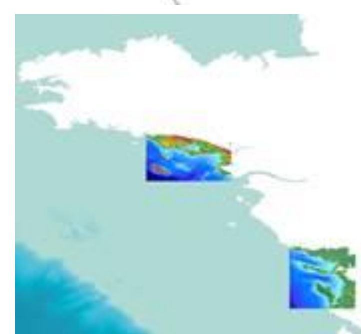
> Base de données nationales

Nouveaux produits SHOM (notamment projet TANDEM)

MNT de façade (~100m) + localement produits fins







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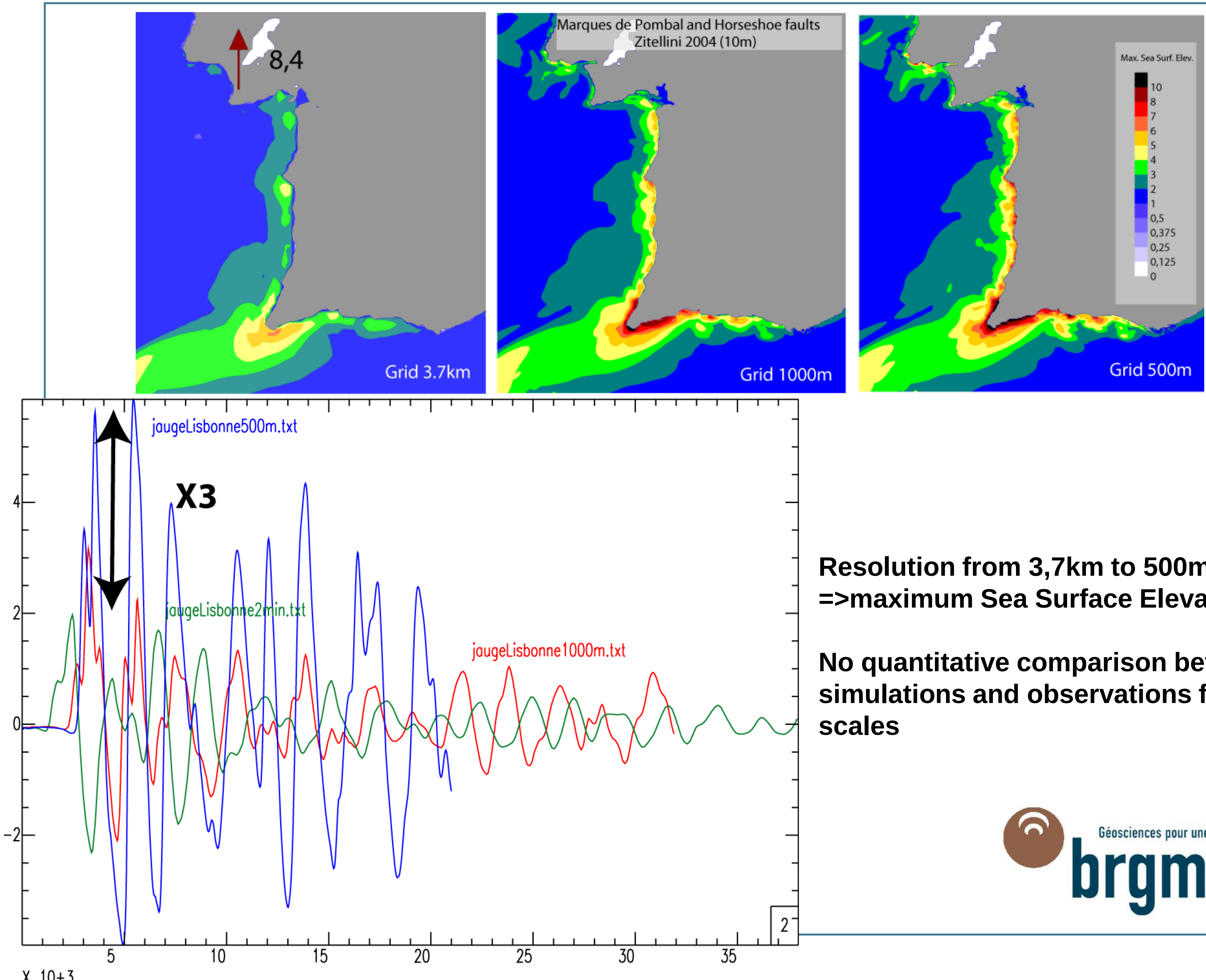

Resolution from 3,7km to 500m =>maximum Sea Surface Elevation X3

No quantitative comparison between simulations and observations for large scales

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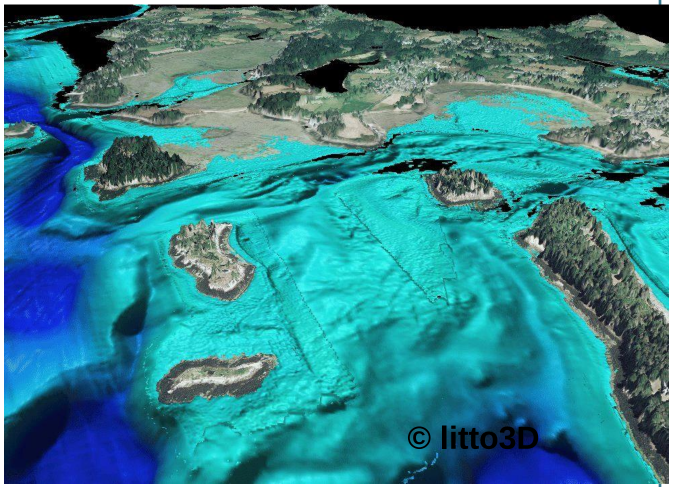
3- topo-bathy : Lidar

Système laser (terrestre / aéroporté)

Précision en z : 5-20 cm

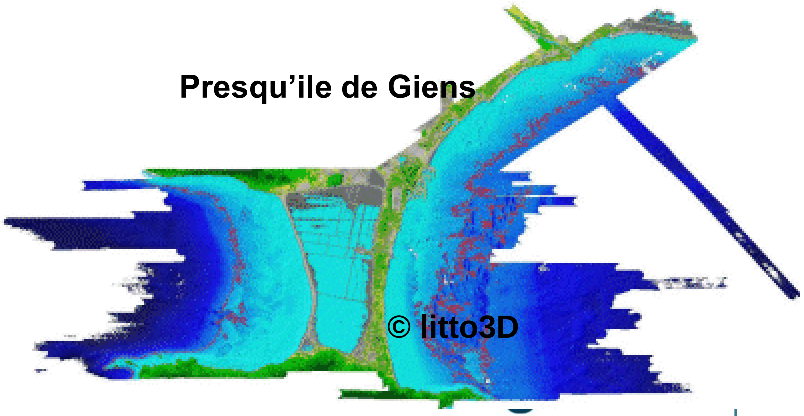
terrestre



Topo-bathy (laser+smf)
(golfe du morbihan)

Toulon

Presqu'ile de Giens



Topo-bathy (laser, jusqu'à prof de 37m)

3- Building database : IGN – Open Street Map, …

- **Building footprint**
- schools, roads, hospital…
- Floors: 1,2,…

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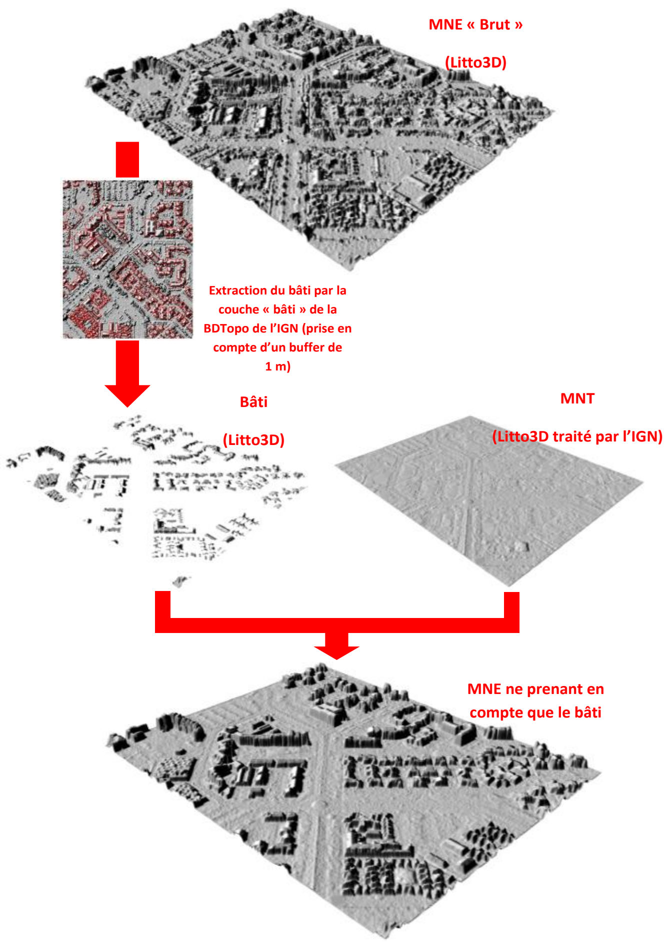
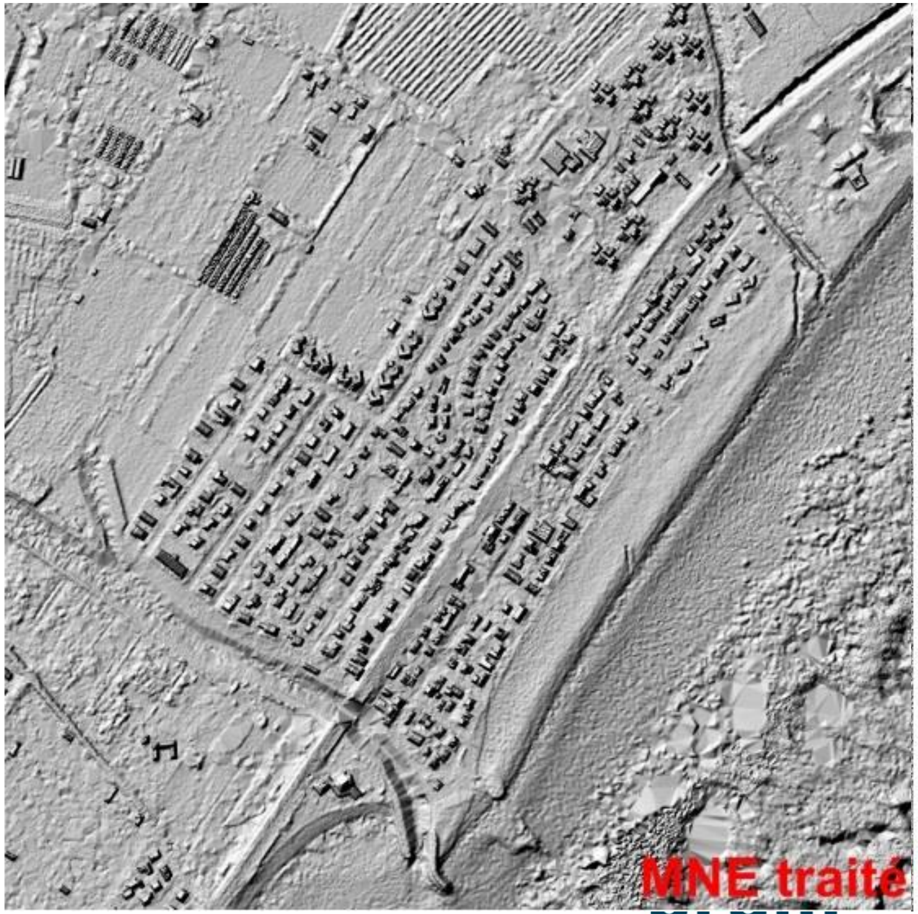
RIS/RIC

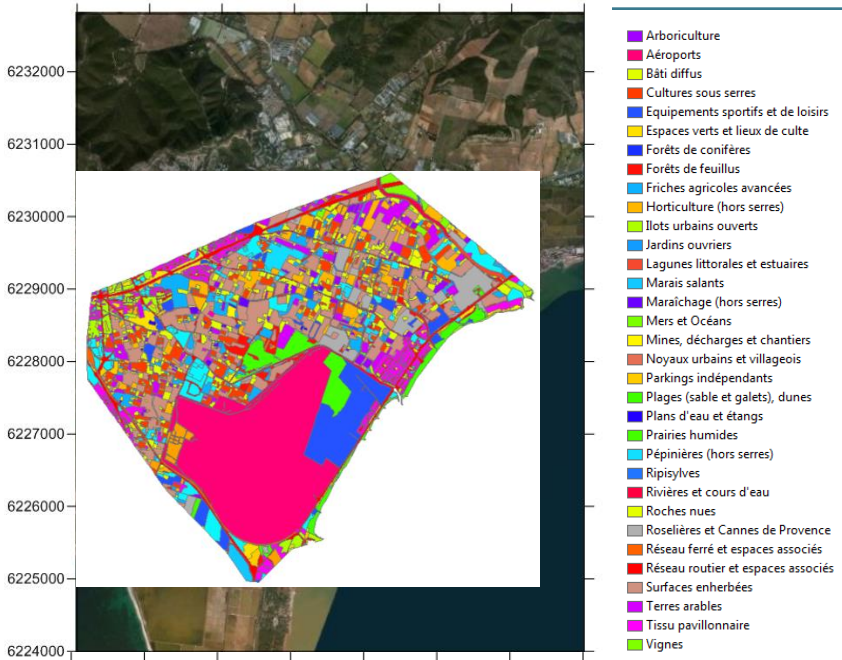
3- Building+DTM: DEM

- Lidar, Litto3D (SHOM-IGN), BDTopo (IGN), Google StreetView, field observations



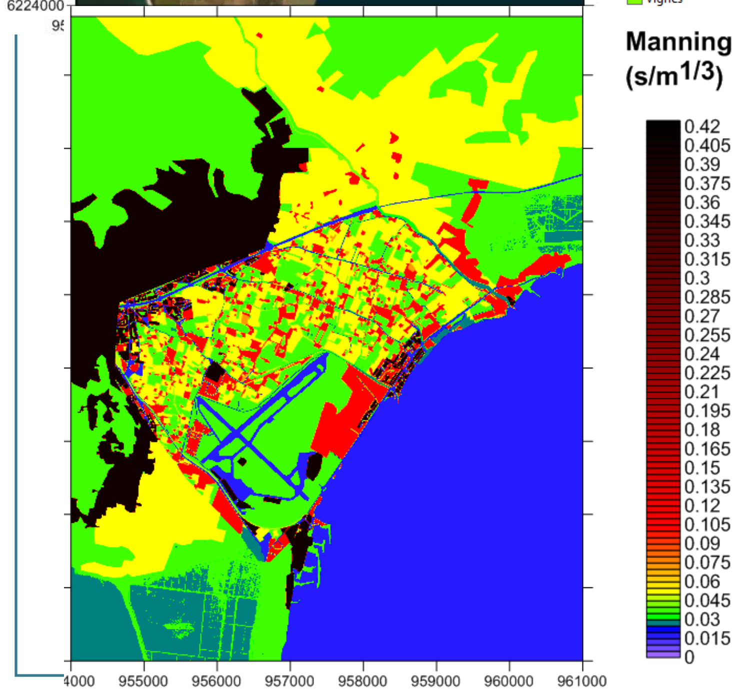


4 - Land-Use: Roughness



MS-GAP class	Description	Manning n
1	Agriculture	0.060
2	Freshwater	0.025
3	Aquaculture	0.045
4	Estuarine water	0.025
6	Farmed wetlands	0.035
7	Estuarine emergent	0.050
8	Estuarine woody	0.060
9	Palustrine emergent	0.055
10	Bottomland hardwood	0.140
11	Riverine swamp	0.060
12	Pine savannah	0.160
13	Freshwater shrub/scrub	0.070
14	Palustrine nonvegetated	0.030
15	Transportation	0.032
16	High density urban	0.150
24	Urban freshwater	0.025
25	Wet soil/water/shadow	0.040
26	Urban pine	0.180
27	Urban hardwood	0.160
28	Urban low herbaceous	0.070
29	Urban grassy/pasture	0.035
30	Bare urban I	0.120
31	Bare urban II	0.120
32	Clear cuts	0.036
50	Low-density pine	0.160
51	Medium-density pine	0.180

Bunya et al. (2010)



Le Roy et al. 2013

Typologie	Manning Chow, 1959 (Min-Norm-Max)	Manning Engineers Australia, 2012	Manning retenu
Béton, asphalte	asphalte (0.013-0.016)	0,02 – 0,03	**0.016**
Prairie	short grass (0.025-0.030-0.035) high grass (0.030- 0.035-0.050)	0,03 – 0,05	**0.04**
Champs	mature row crops (0.025-0.035-0.045) mature field crops (0.030-0.040-0.050)	buissons: 0,05 – 0,07	**0.05**
Urbain dense		0,2 – 0,5	**0.4**
Urbain éparse		0,1 – 0,2	**0.1**
Forêt dense	heavy stand of timber, a few down trees, little undergrowth, flood stage below branches (0.080-0.100-0.120)	0,07 -0,12	**0.1**
Forêt éparse	cleared land with tree stumps, no sprouts (0.030-0.040-0.050)		**0.04**
Surface en eau		0,02 – 0,04	**0.03**
Sol fortement rugueux	0.050-0.070-0.080		**0.07**
Sol moyennement rugueux	0.035-0.045-0.05		**0.045**
Sol faiblement rugueux	0.025-0.030-0.033		**0.03**

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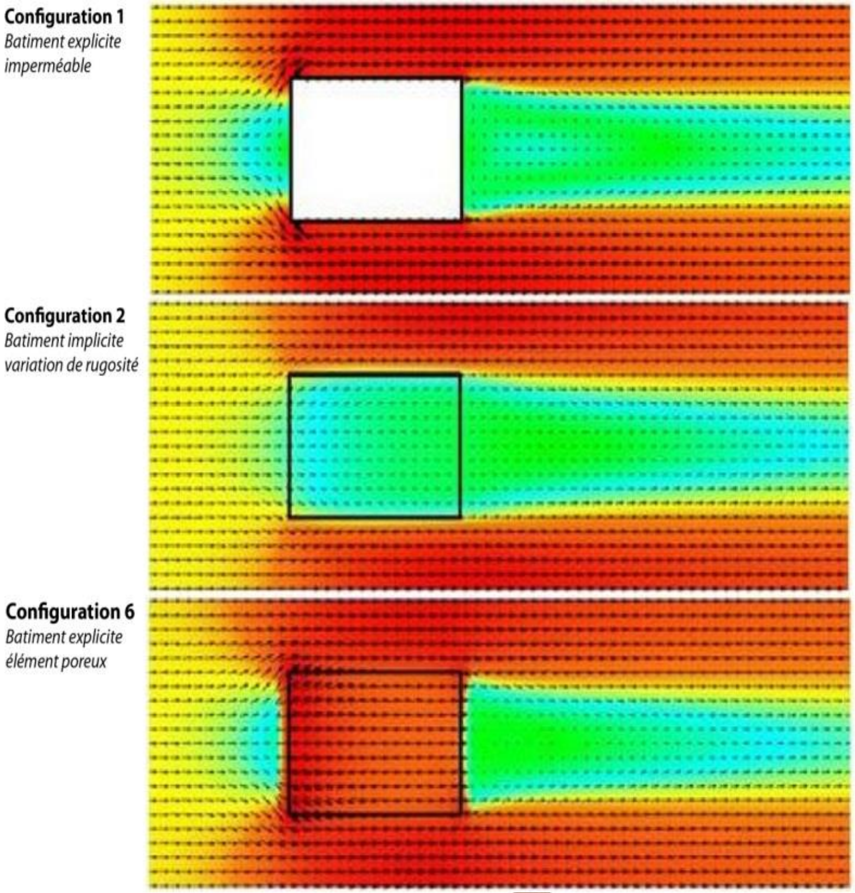
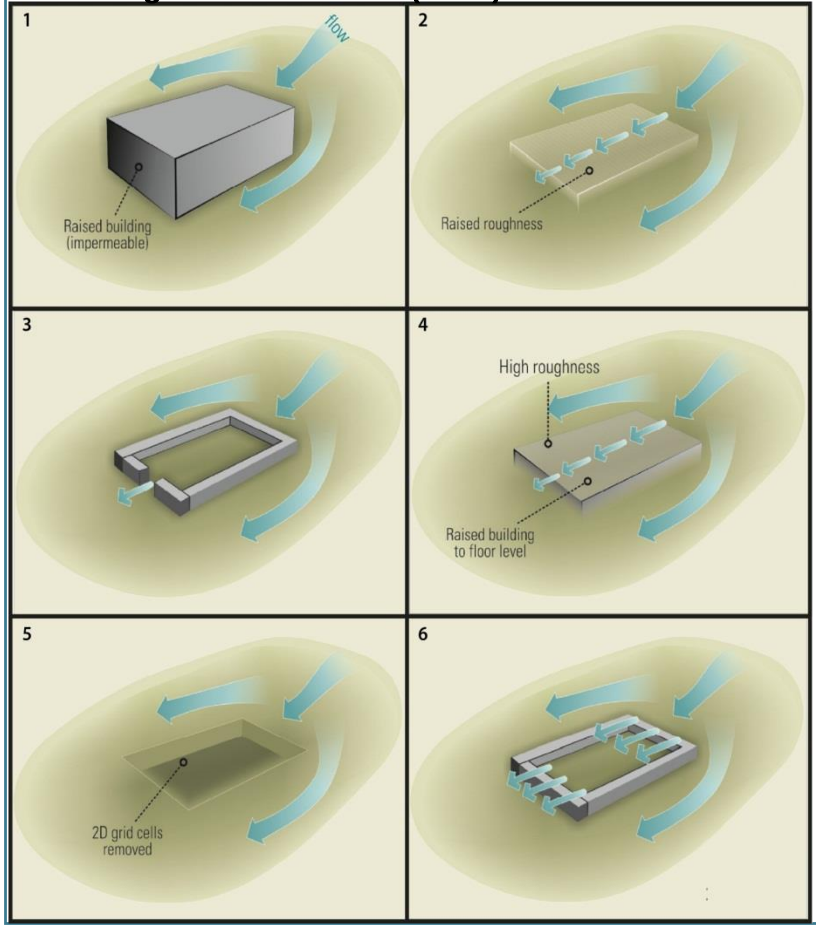
3 and 4: building representation models

Syme, 2008



Engineers Australia (2012)



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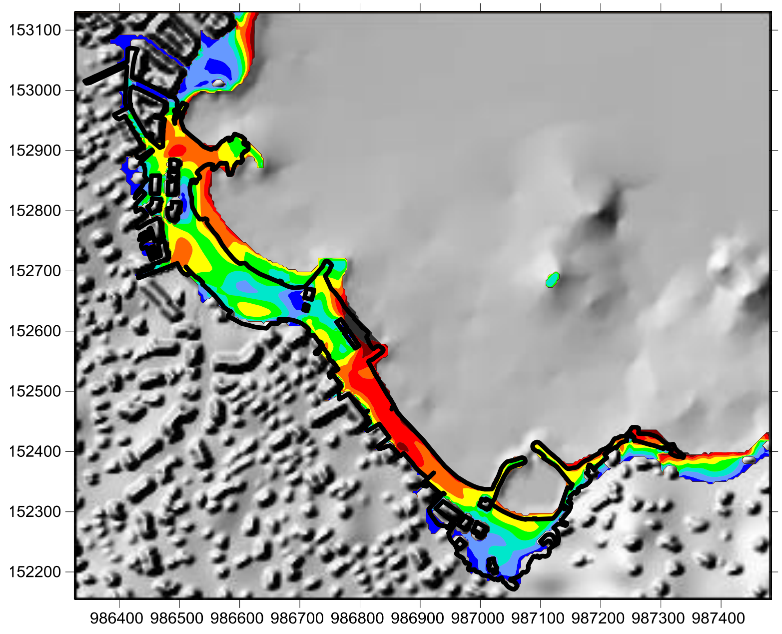
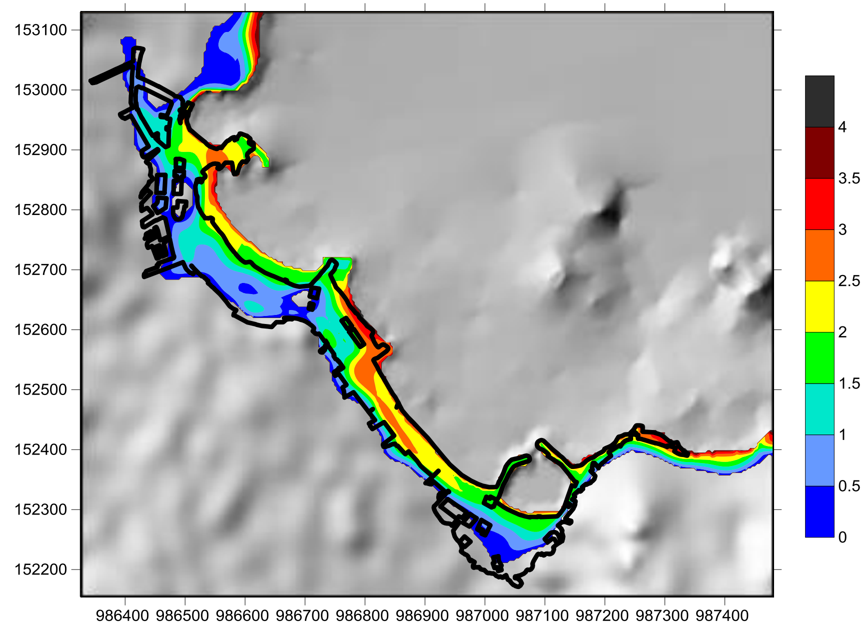
4- Coastal flooding vs representation of urban areas

Exemple Tsunami de Nice 1979



Impermeable blocks



Raised roughnes

Le Roy et al. (2011, 2014)

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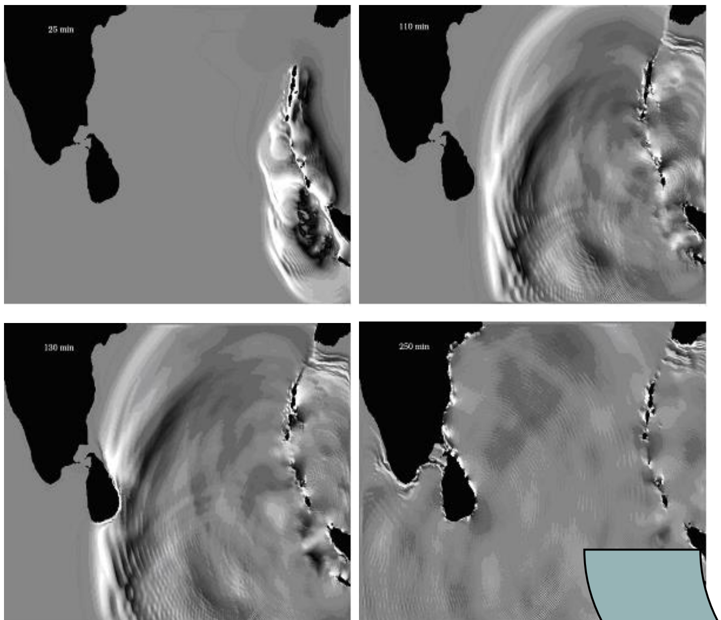
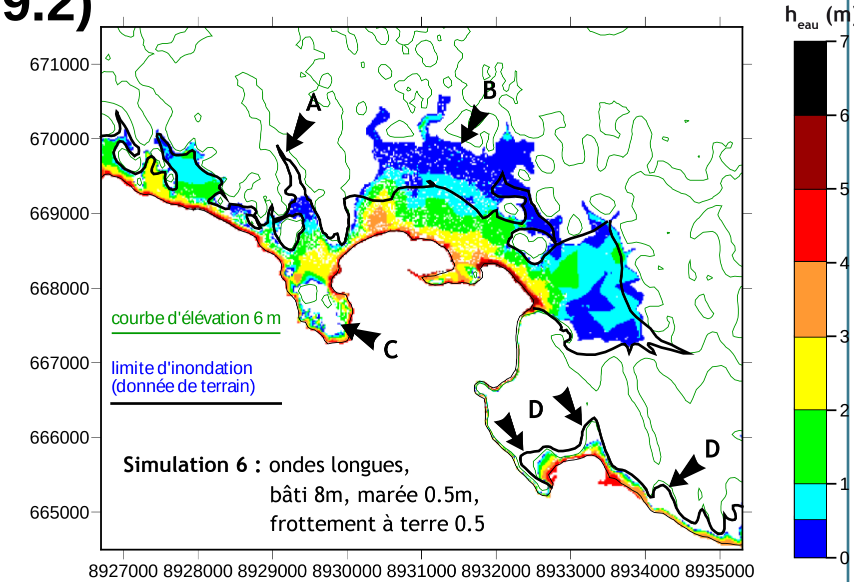
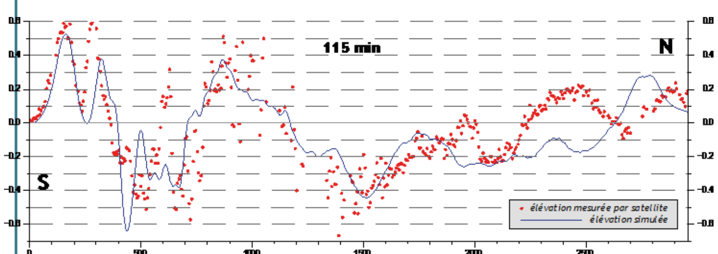
SUMATRA 2004 (Mw 9.2) –Sri Lanka

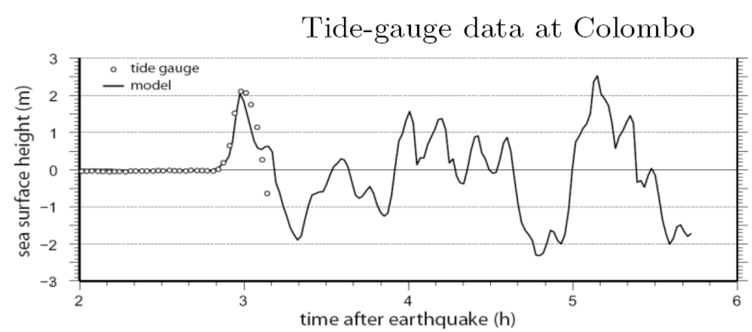
Tsunami modeling : dec 2004 - **(Mw 9.2)**





- **Nested grid -> 20m**
- **Homogeneous rougness**





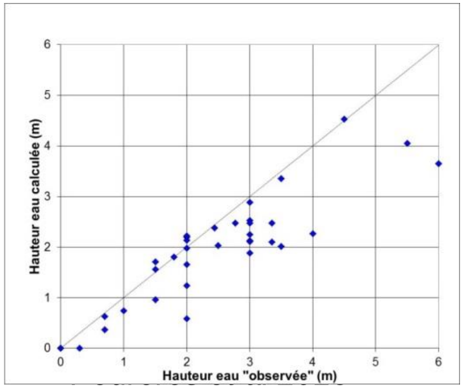
Poisson, Garcin et Pedreros, GJI, 2009

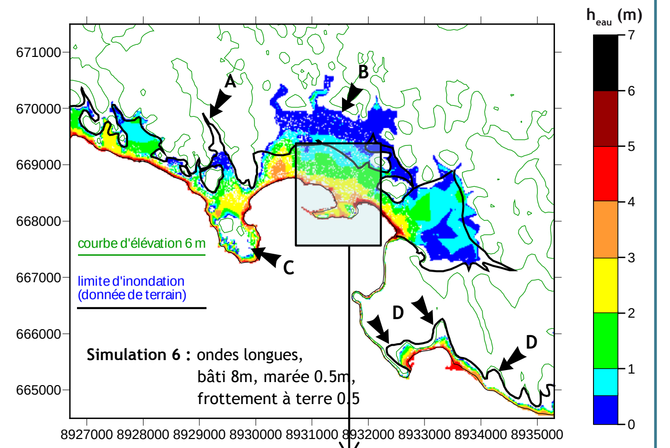
SUMATRA 2004 (Mw 9.2)

Inundation calculation at Sri Lanka (Galle bay)

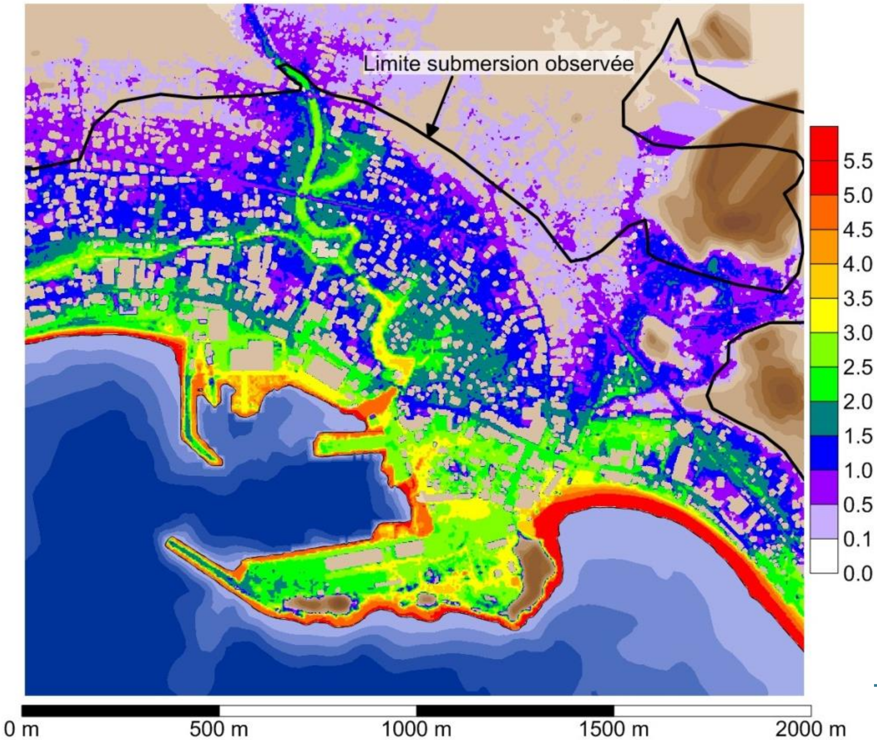
- Nested grid -> 2.5 m
- Buildings (Lidar datas)
- Land use

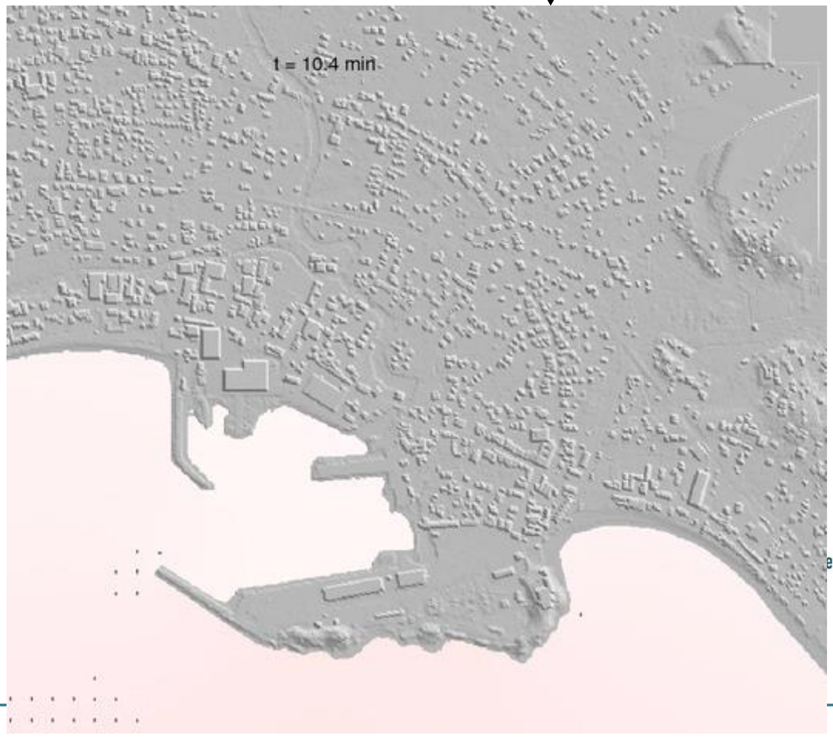
Pedreros et al. 2013



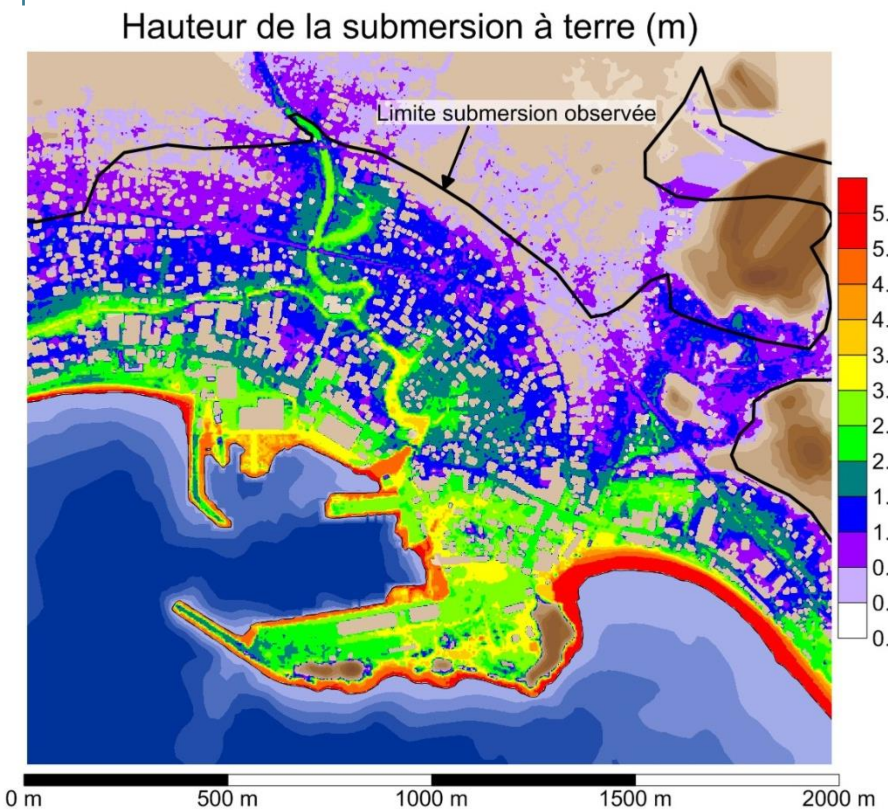


Hauteur de la submersion à terre (m)

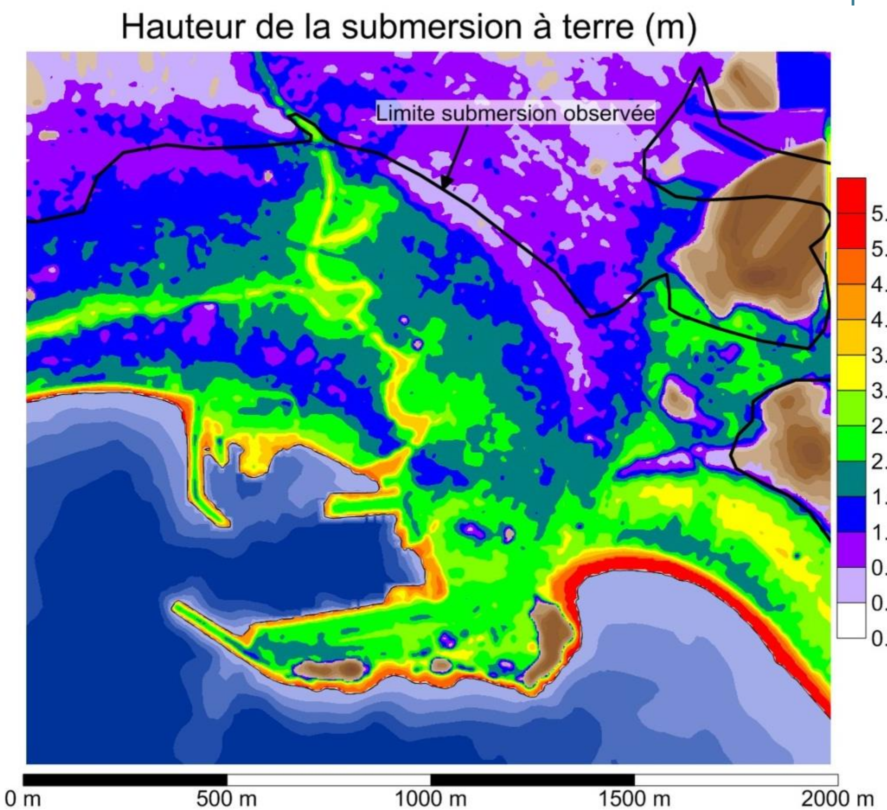




Inundation – Water height



With buildings and structures



Without buildings and structures

Pedreros et al. 2013

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RIS/RIC

A- Tsunami Hazard Evaluation

1-Historical database

2-Water level measurements – Field observations

3- Topo-bathymetry – Building database

4- Land-use

B- Evaluation of assets vulnerability

1- Damages to buildings

2-Damages to people

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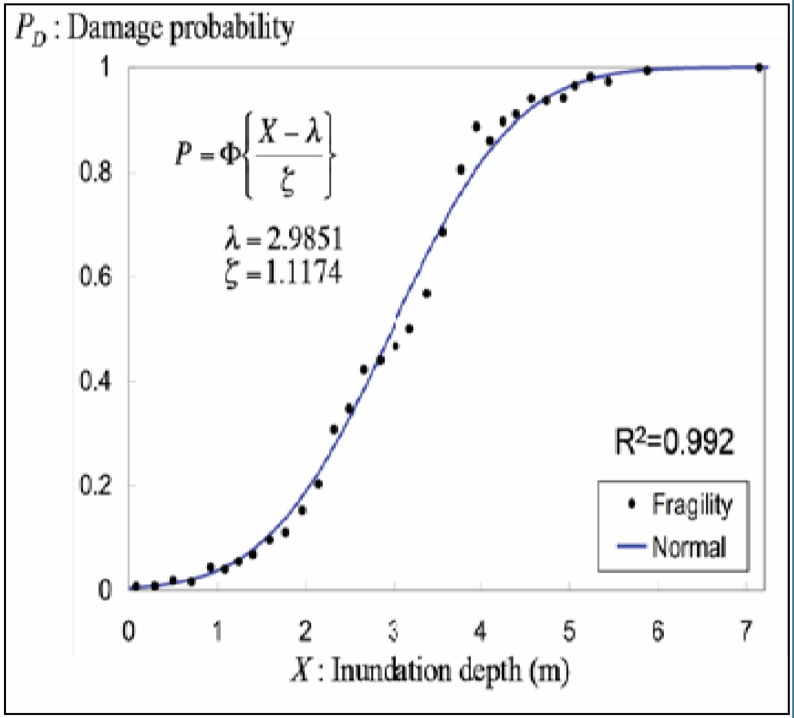
B-1 : Damages to building

After the tsunami of 2004, several methods have been developed.

They concern the damage to buildings, and are therefore limited to scenarios of tsunami of high to very high intensity (5-6 of the Sieberg-Ambraseys scale degrees).



Example: function of damage proposed by Koshimura (2007) for all types of building

B-1 : Damages to building – Sri Lanka

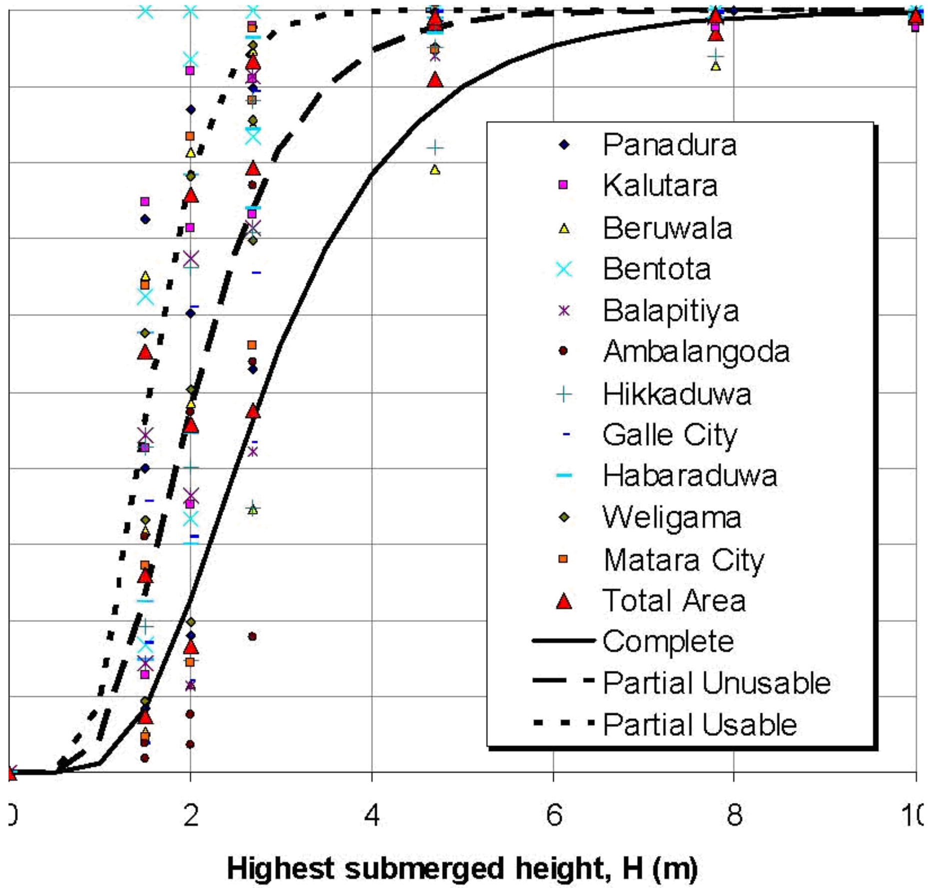


Figure 4: Vulnerability functions for southwest of Sri Lanka

Peiris, 2006

Example of Sri-Lanka: Typology & Damage scale

Buildings typology (SW Sri Lanka)

- ***L*** : light (wood, sheet metal…) ;
- ***B1*** : light bricks;
- ***B2*** : 2 ranks of bricks ;
- ***CB1*** : concrete blocks, bad quality;
- ***CB2*** : concrete blocks, good quality with concrete columns;
- ***C*** : reinforced concrete;
- ***LB*** : traditional in rubblestones.

Damage scale

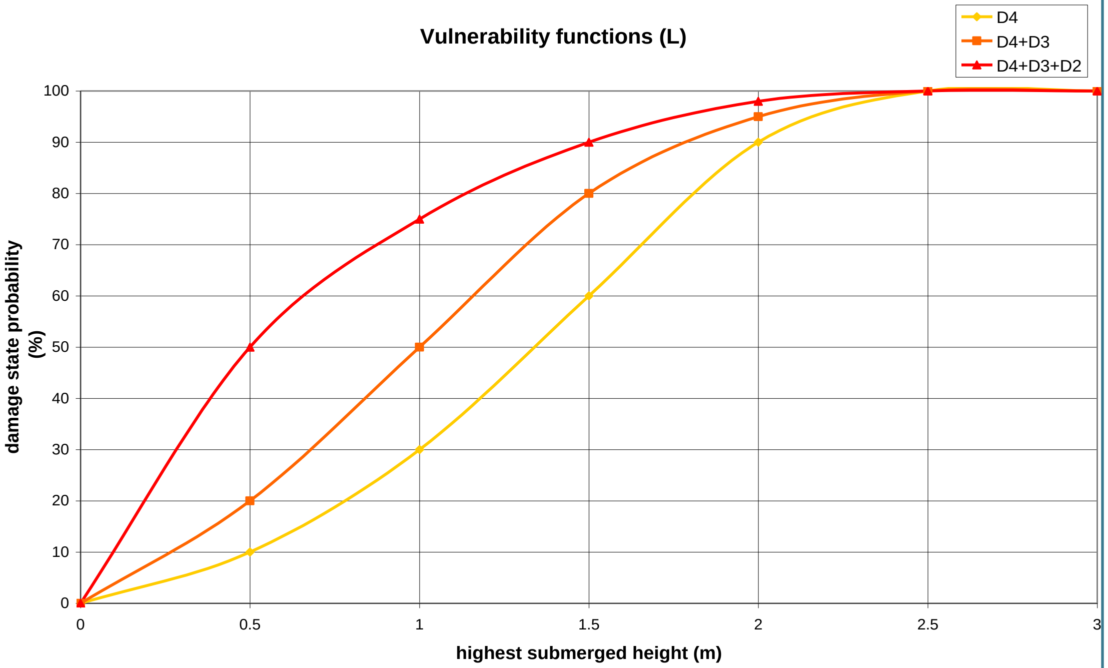
- 5 classes (D0 to D4) :
  - *D0* : superficial damages, no structural damages.
  - *D1* : cracking, destruction of windows and doors, habitable and repairable ;
  - *D2* : collapsing of walls without damages to the building integrity, moderate scouring of fundations, not habitable but restorable ;
  - *D3* : destruction of several bearing walls, important scouring of fundations, not restorable ;
  - *D4* : total destruction of the building ;

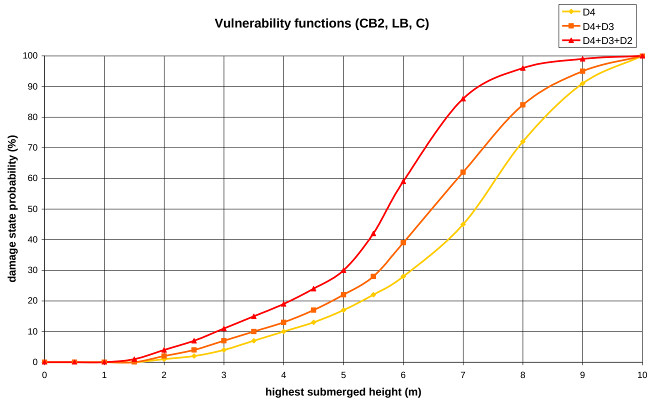
Garcin et al. 2008

Example of Sri-Lanka: vulnerability curves from the 2004 Sumatra Tsunami

To each building type is associated a damage function by tsunami, based on post-event observations.

This damage function is a curve giving the damage probability (from D4 to D1) depending of the inundation height affecting the building.





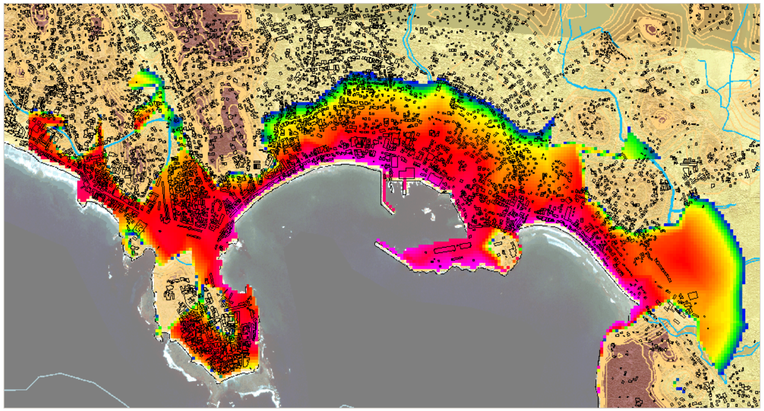
lurable

Example of Sri-Lanka:

After validation by field visits, mapping is made through a GIS tool developped by BRGM (Armageddom)

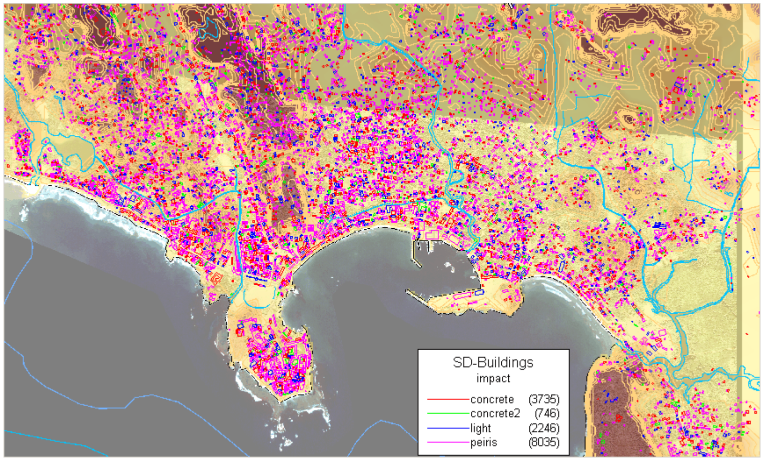
Inundation height (from models)

1



Statistical attribution of building typology to each building

2

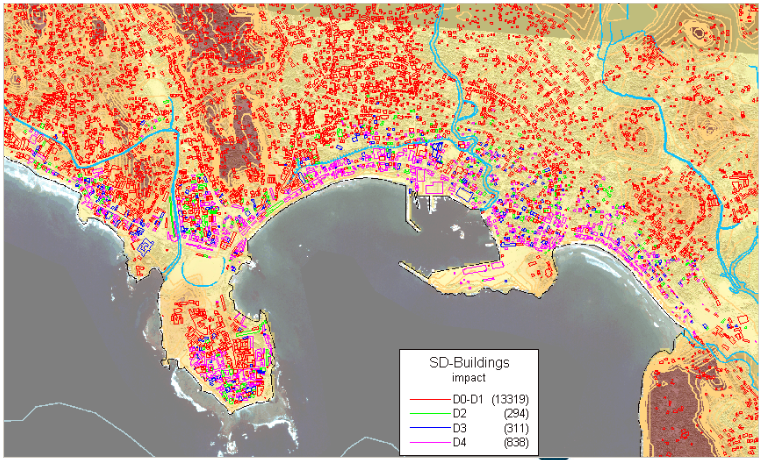


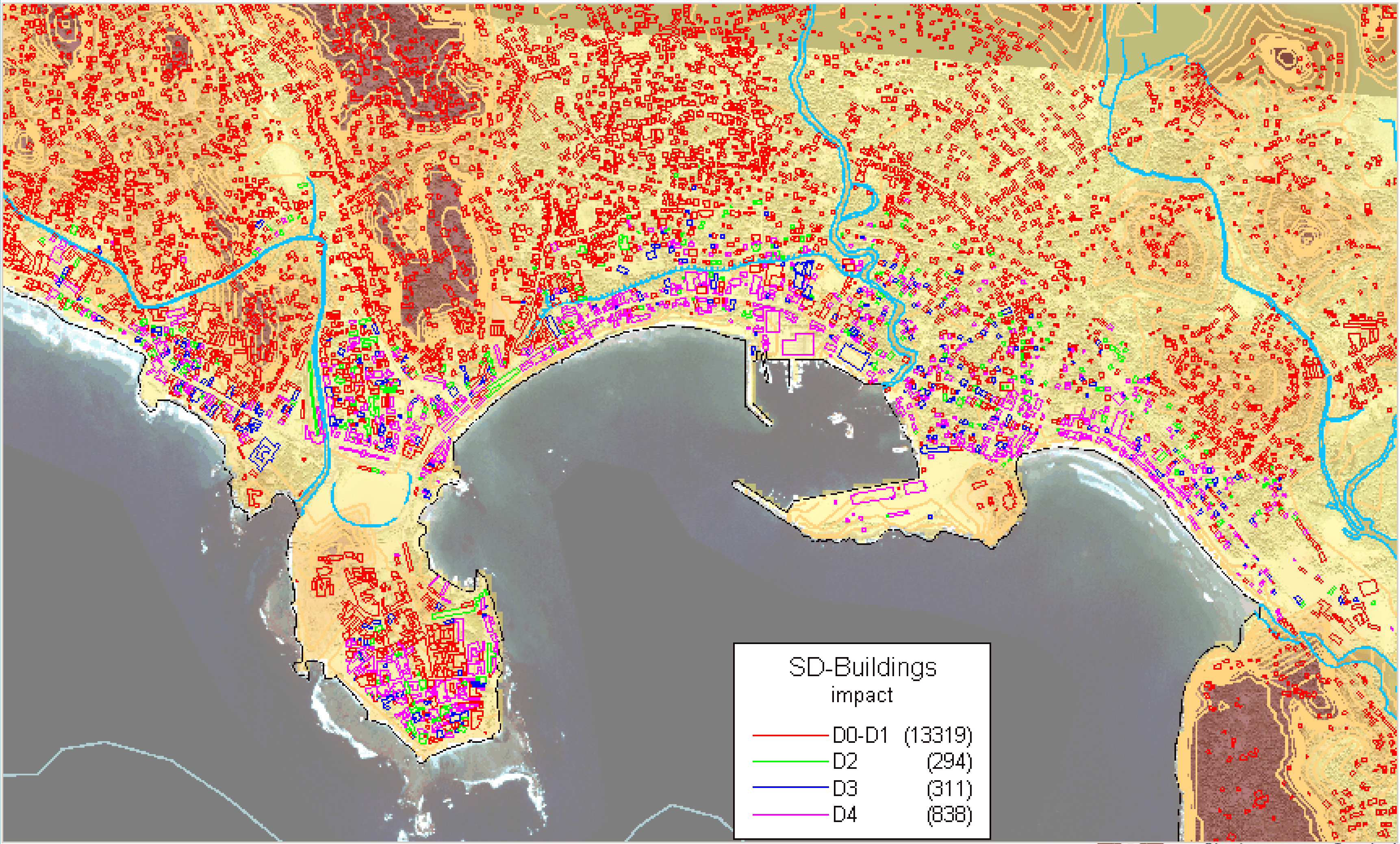
Quantification of the agression for each building

3

Damages for each building

4





Garcin et al. 2008

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RIS/RIC

Damages to people: example of Nice 1979

On the Mediterranean French coast : low to medium exposition to tsunami

⟹few damages expected on structures

Most of the work concerns people vulnerability, and damages in harbors, distinguishing:

- Season (touristic zones)
- Location (inside/outside the buildings)
- For people inside buildings, the type of building (is it a refuge or a trap ?)

People vulnerability is based on their ability to move and to resist to the flooding

⟹Knowledge from fluvial inundations

⟹Based on inundation height / current

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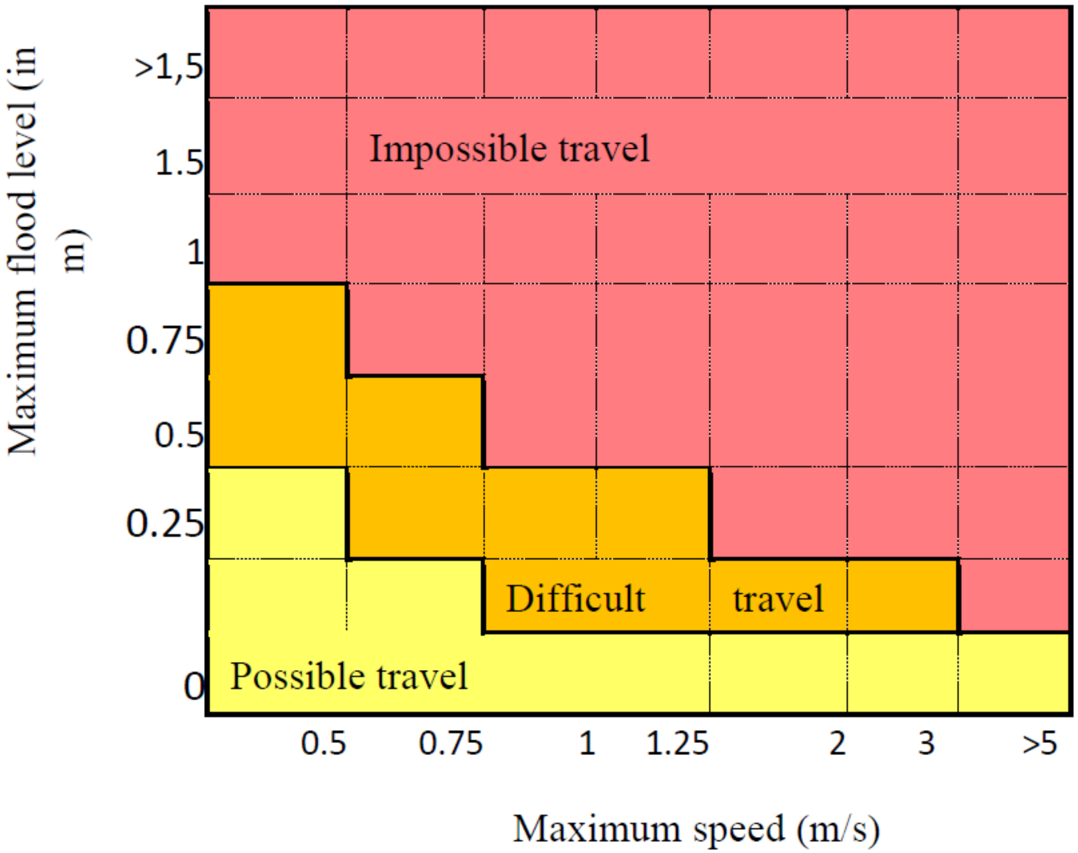
Population located outdoors:

Limit of ability to move for persons located outside



For an affected population unable to move and situated outdoors, **a mortality rate or strong injuries of 10% was determined:**

average fixed on the basis of the tsunami of Indonesia and Japan (Gusha-Sapir (2006), Nishikiori et al.) (2007) & Mimura et al. (2011)

> Classification in 4 levels of exposure

Typology of the structure

multi-story building surmounting a transparent ground floor (presence of shops, bay-windows...)

A multi-story building surmounting a closed ground floor

A transparent one-story building (ground floor).

A one-story building (ground floor) with walls

0 : building not flooded

1 : building flooded, but **people on the ground floor can move around.**

1,5 : single-level building, flooded. **People can move around but they have no place to take refuge.**

2 : building flooded. **People on the ground floor are swept away or trapped.**

RIS/RIC

Assessing vulnerability of the stakes

For a **population trapped on the ground floor** of buildings exposed to level 2 conditions, based on work by Guha-Sapir (2006), a **4% mortality rate** is obtained.

Underground levels (basements and car parks) constitute a specific type. The risk is considered to be **level 2** once flooding reaches them.

For aggressions higher than those appertaining to levels 0 to 2, the behavior of the structure can be estimated using vulnerability curves derived from observations of the 2004 Indian Ocean tsunami or those proposed by Guillande *et al.* (2009), Garcin *et al.* (2007), Peiris (2006), and Léone *et al.* (2006).

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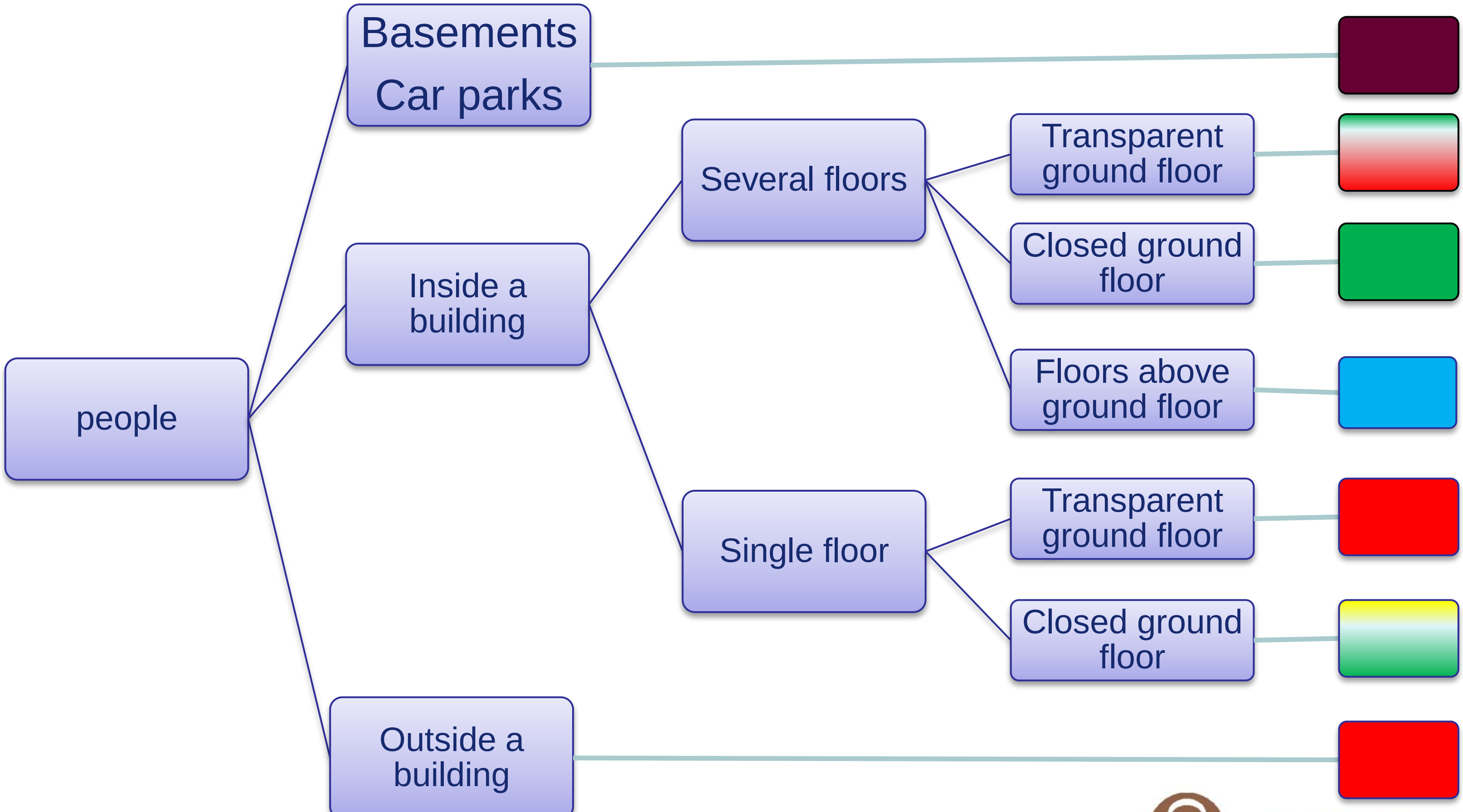
People vulnerability :

in each case, a matrixe of exposure is used



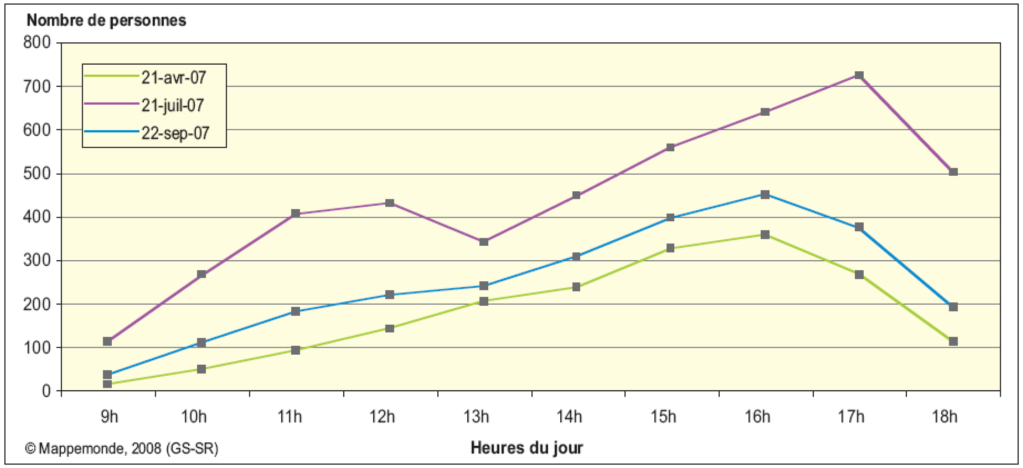
Caractérisation de la zone

> **Milieu bâti (BD topo IGN ©)**

- Délimitation individuelle du bâti
- Nbe étages

> **Secteurs extérieurs**

- Délimitation plages & promenades
- Caractérisation fréquentation manière qualitative
- Estimation nb personnes par site été / hiver / jour nuit
- Localisation fréquentation des campings, des



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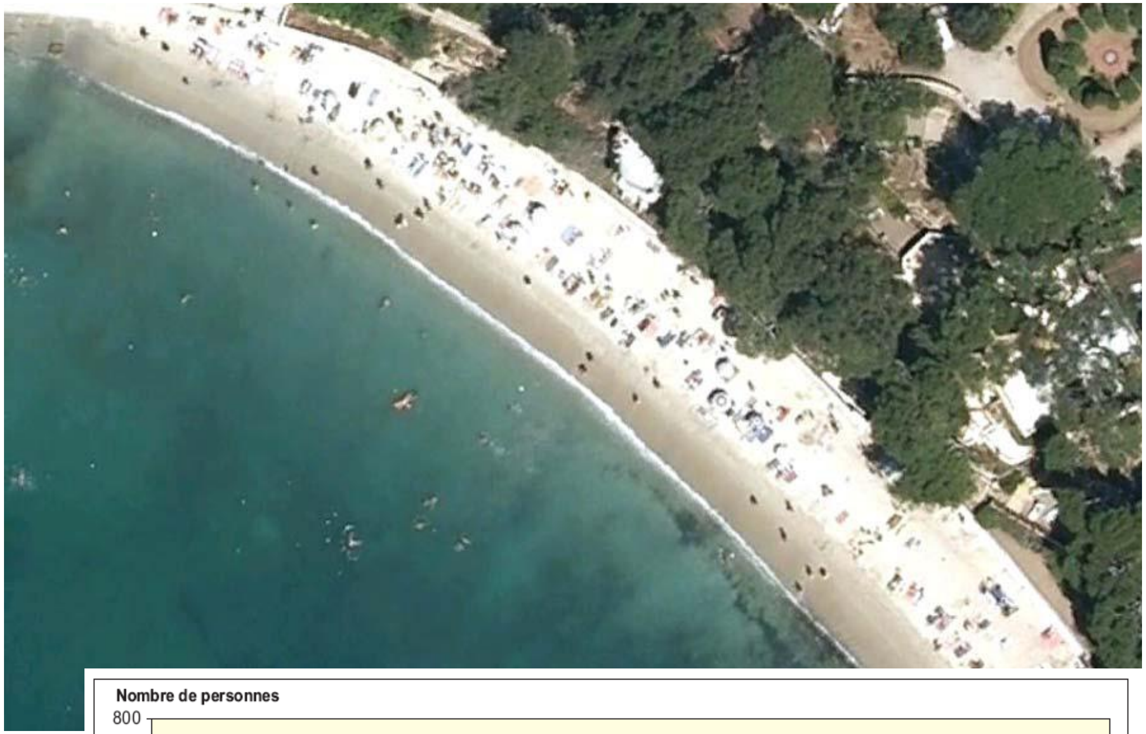
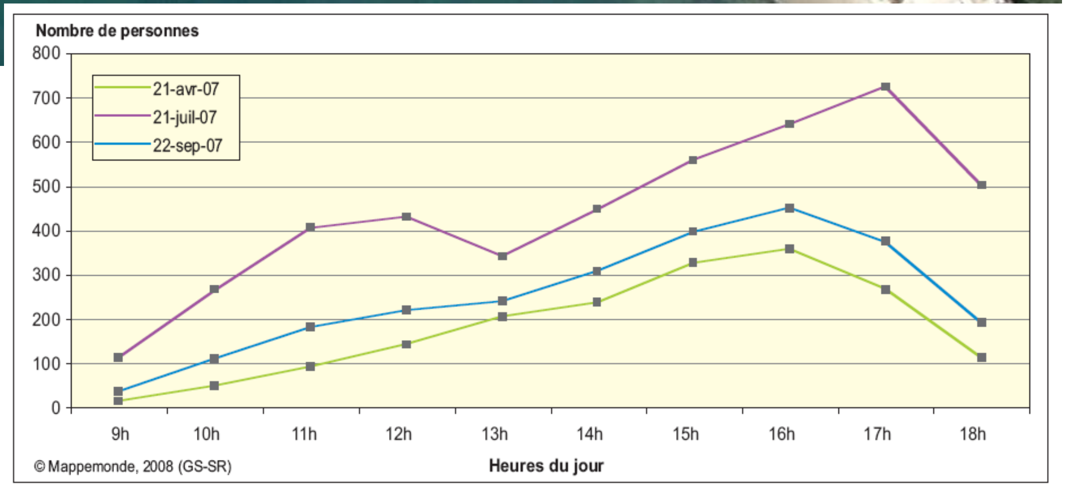
Beach density population





- > **Density estimation during summer**
- > **Google earth**
- > **Tourism observatories**
- > **Some specific works (Robert et al. 2008 Nice)**

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tsunami type 1979 : Damage assessment

Scenarii with:

-the current distribution and typology of the built environment,

-the population density in 2010, off-season and during tourist season.

Four time scenarios:

mid-January 2012 at 2 a.m. and 3 p.m.

mid-August 2012 at 2 a.m. and 3 p.m.

La Salis (Antibes) beach

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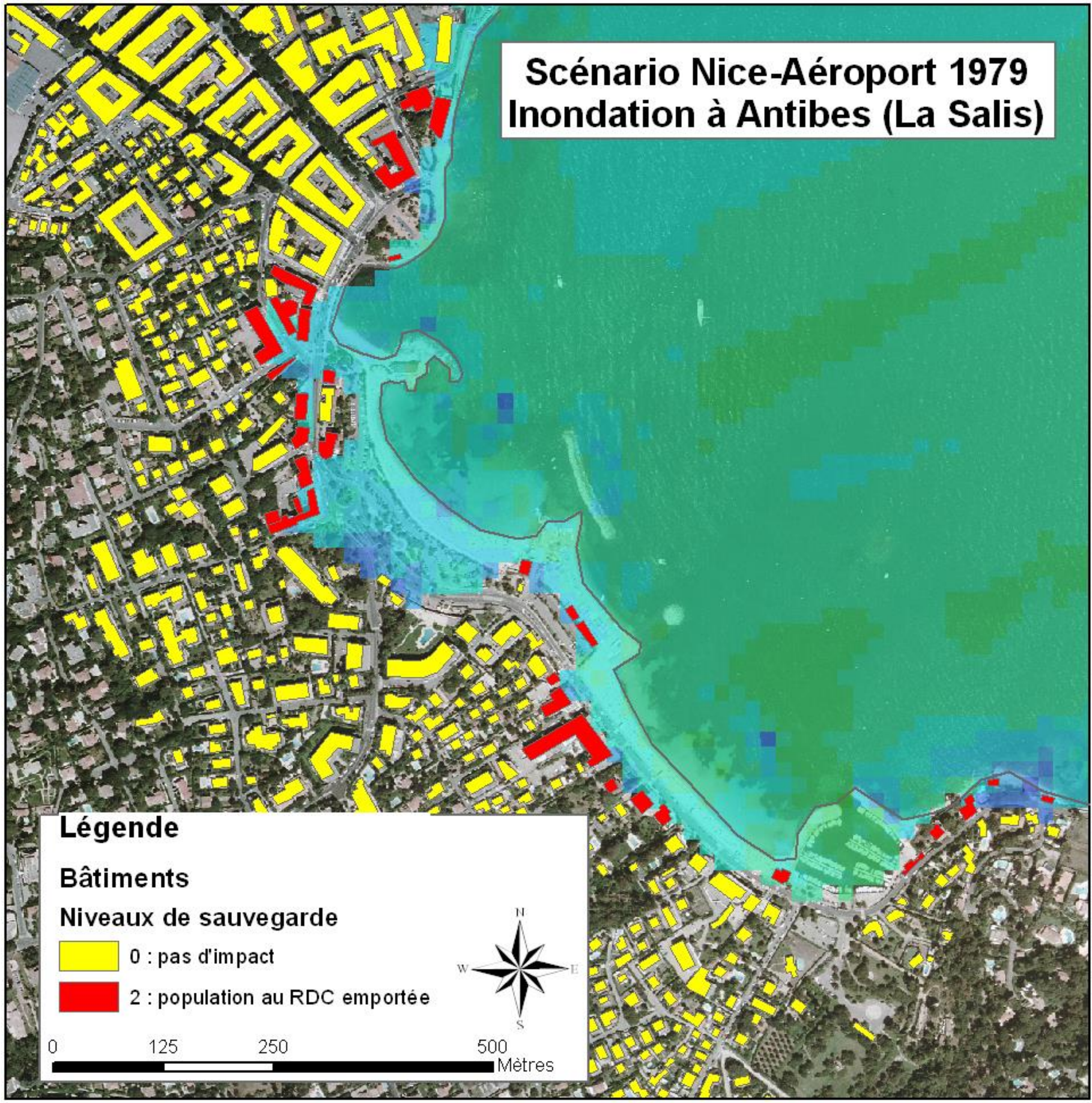
Résultats : la Salis (Antibes)

- 42 bâtiments impactés par le flot (population RDC emportée)
- Dommages faibles du bâti (sauf structures très légères comme terrasses, etc.)



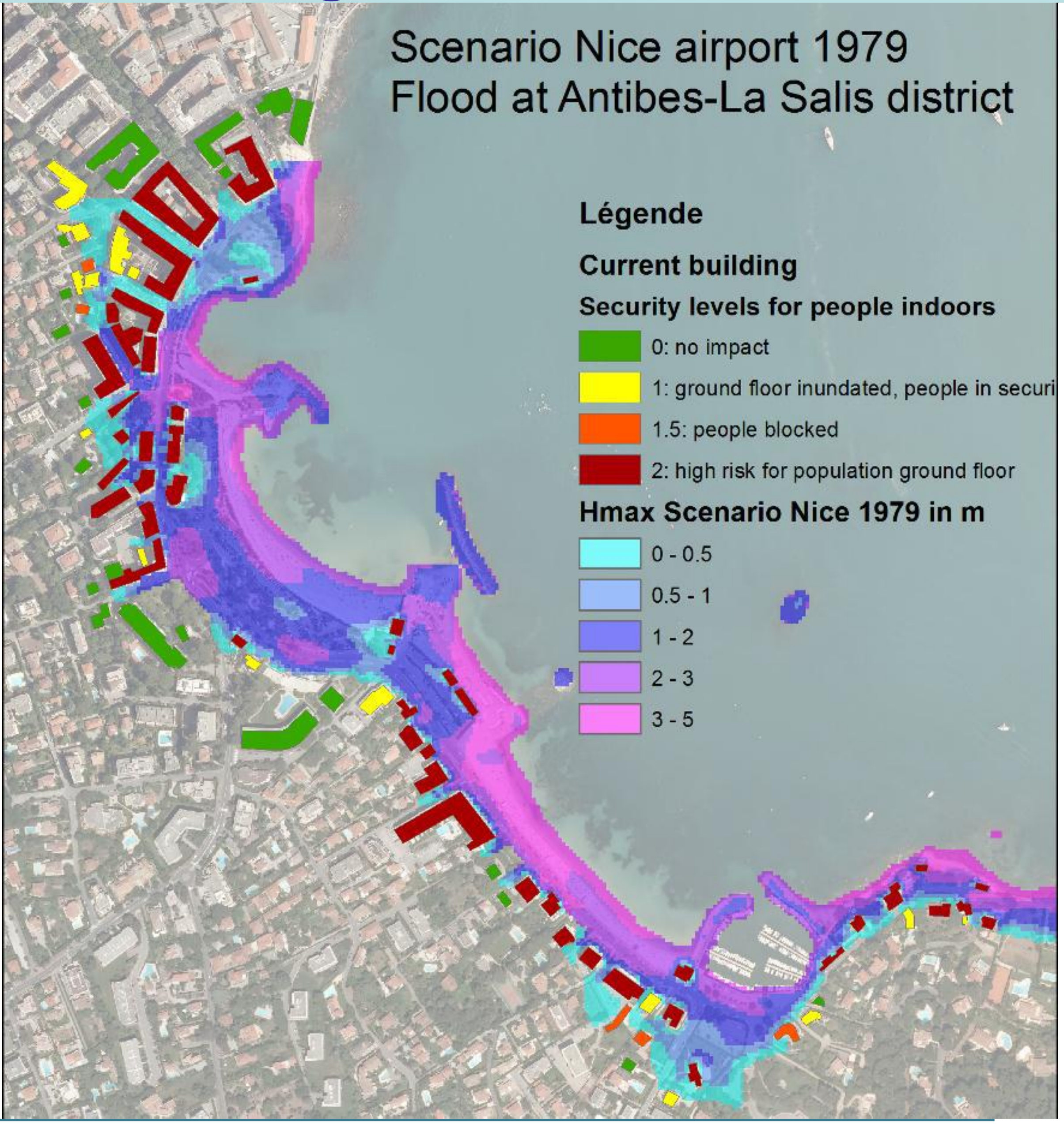
tsunami type 1979 : Damage assessment

68 buildings affected by the inundation, with

-25 would undergo a run-up height exceeding 0.75 m,
-34 would be subjected to a current speed of over 1.5 m/s

➢**42 would present an exposure level of 2** (impossibility for persons inside to escape)

Terrier et al., 2013



tsunami type 1979 : Damage assessment

Human losses at La Salis (Antibes)

People outside

La Salis quarter, tsunami type 1979, people oudoors	**People unable to withstand the flood**	Number of deaths or serious injuries
August 15th in mid-afternoon	2000 to 4000 people	200 to 400
January in mid-afternoon	60 to 80 people	5 to 10

People inside building with an exposure level of 2,

on August 15th :

•200 in the middle of the afternoon > 5 to 10 deaths or serious injuries

•300 at night > 5 to 15 deaths or serious injuries

On Juanary :

•90, in the middle of the afternoon > less than 4 deaths or serious injuries

•150 at night, > 3 to 6 deaths or serious injuries

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Terrier et al., 2013

MERCI

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