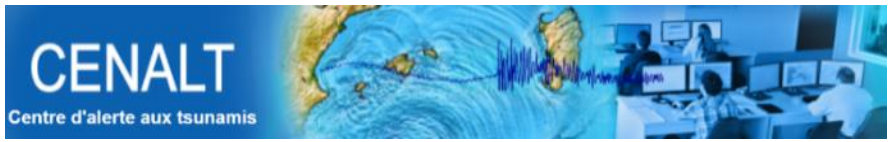
Expert Meeting on Tsunami Sources Associated with Hellenic Arc and Azores–Gibraltar Fault Zone in the North-Eastern Atlantic, the Mediterranean, and Connected Seas (NEAM) Region

Tsunamigenic sources in the NEAM region: Focus on Atlantic and western Mediterranean scenarios

Hélène Hébert, CEA, DAM, DIF, Arpajon, France

with Audrey Gailler, Philippe Heinrich



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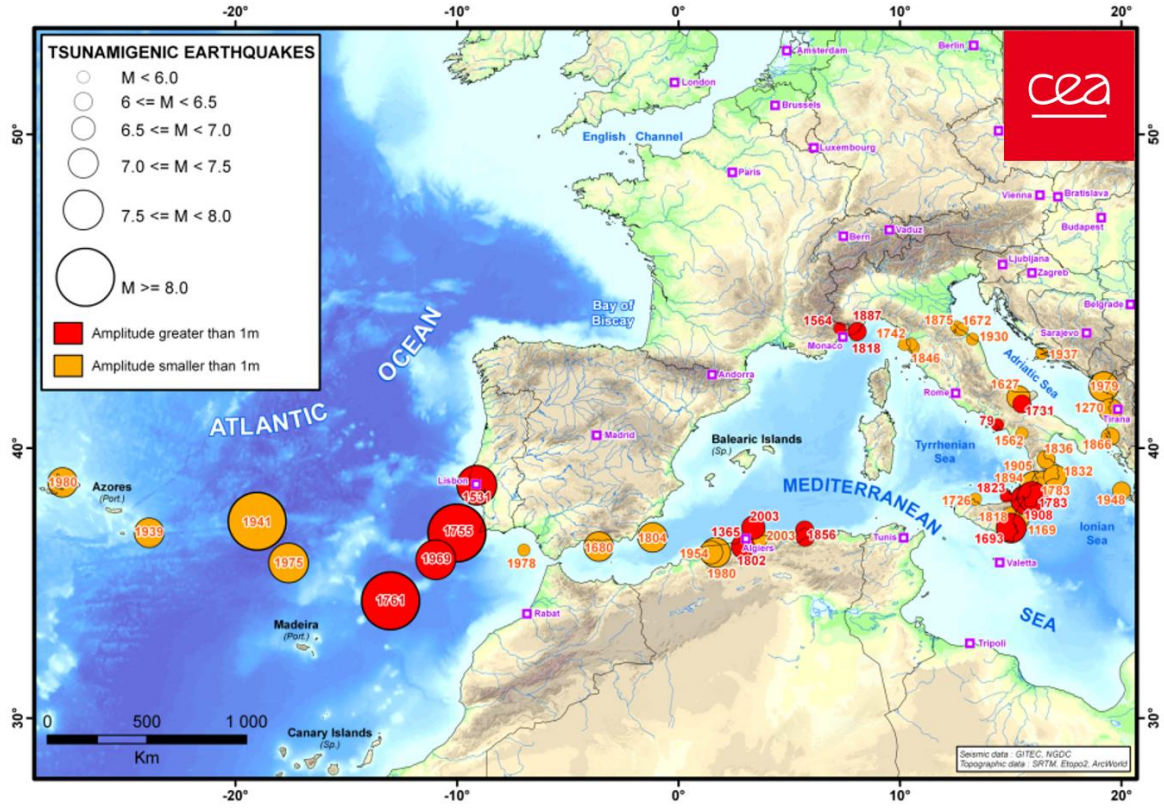
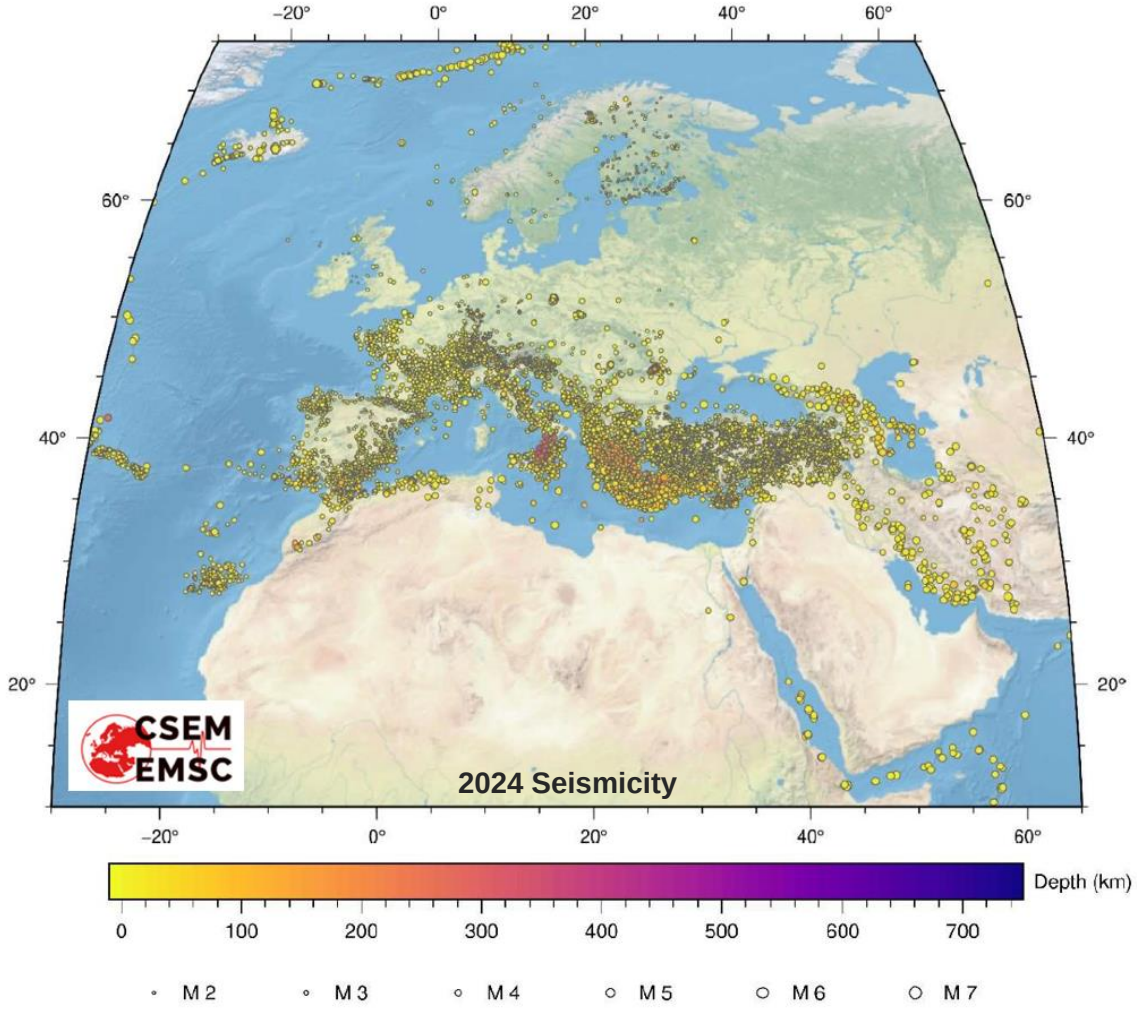
5. Some lessons



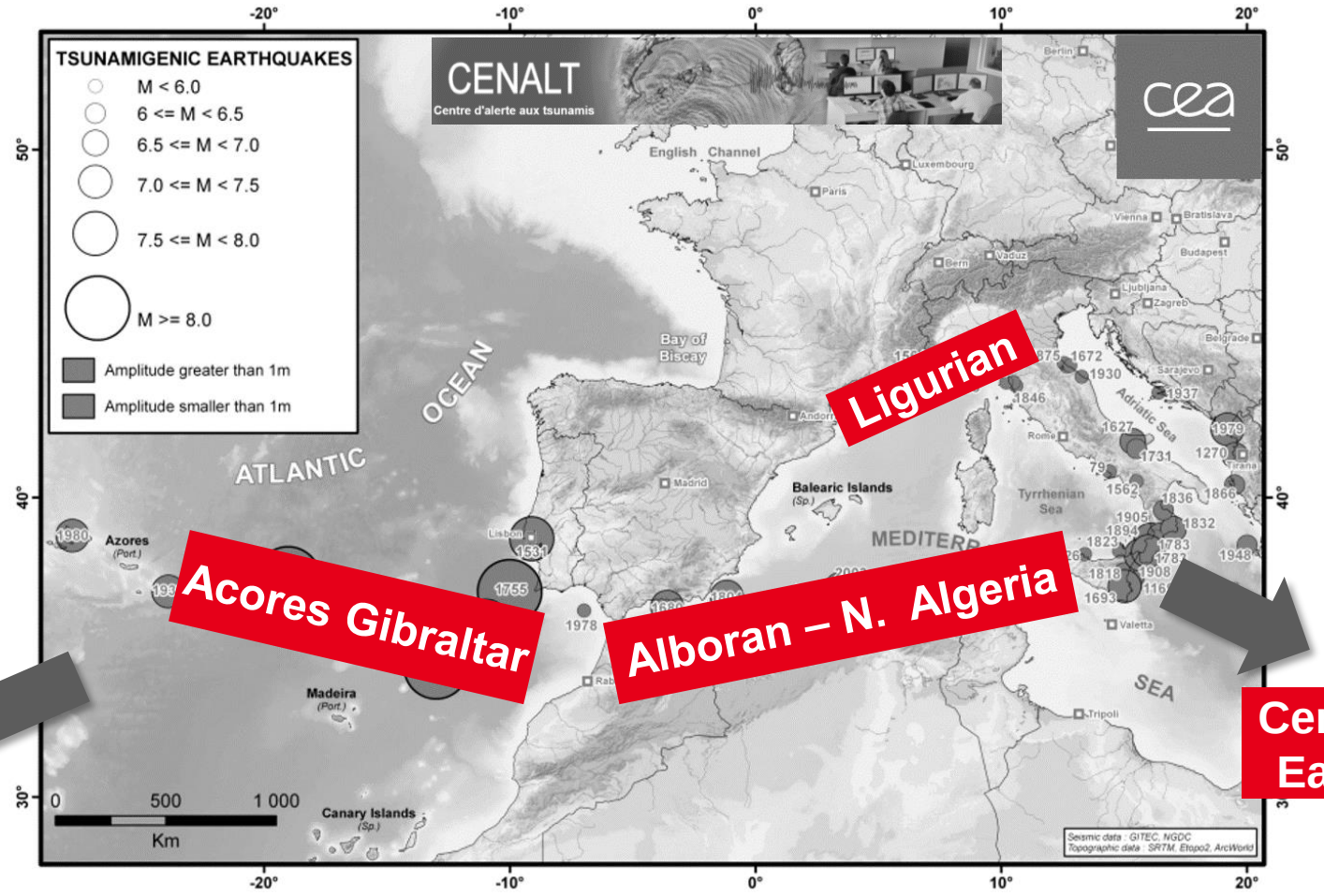
Approach

- **Seismotectonic assessment**
  - Active faulting can be defined from historical events and instrumental seismicity
  - + Detailed investigation is essential and poorly available offshore
  - Definition of possible mechanisms
- **Tsunami observations** and data
- **HR Tsunami modeling**
  - Discussion on plausible mechanisms
  - Compared to coastal observations
  - Deterministic / Probabilistic
  - Future scenarios
- **Focus on possible impacts** on the coastlines



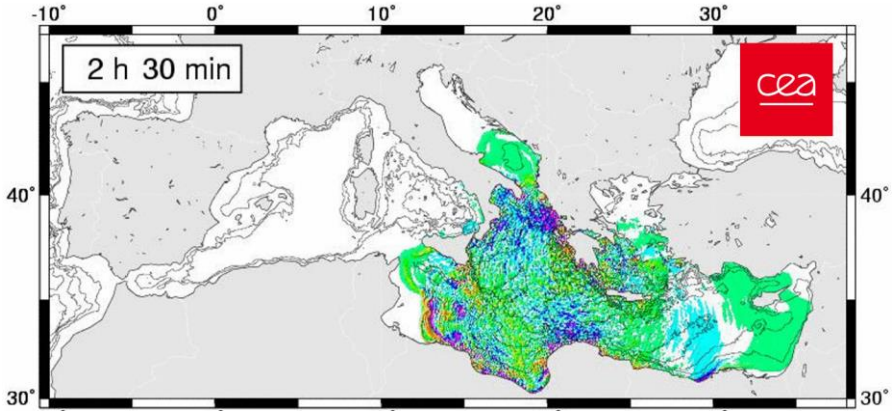
Which tsunamigenic sources for NEAM

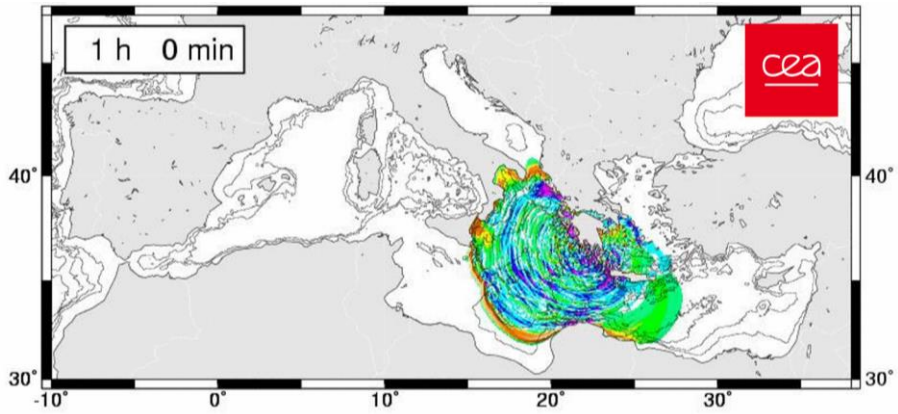
- A complex context of tectonic convergence
- Major tsunamis already occurred in the past
  - M > 8 possible in East Med
  - M ~ 7 to 7.5 in West Med
  - M > 8 in the Atlantic
- With various return periods
- Landslide sources
  - Including postseismic

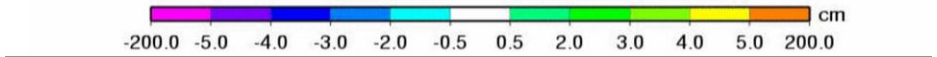


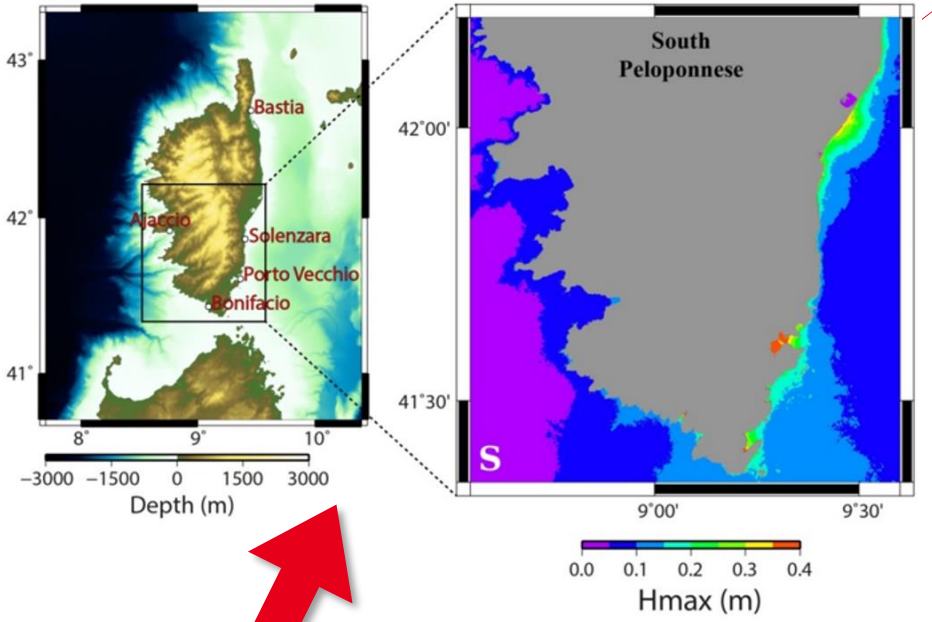
Eastern Mediterranean

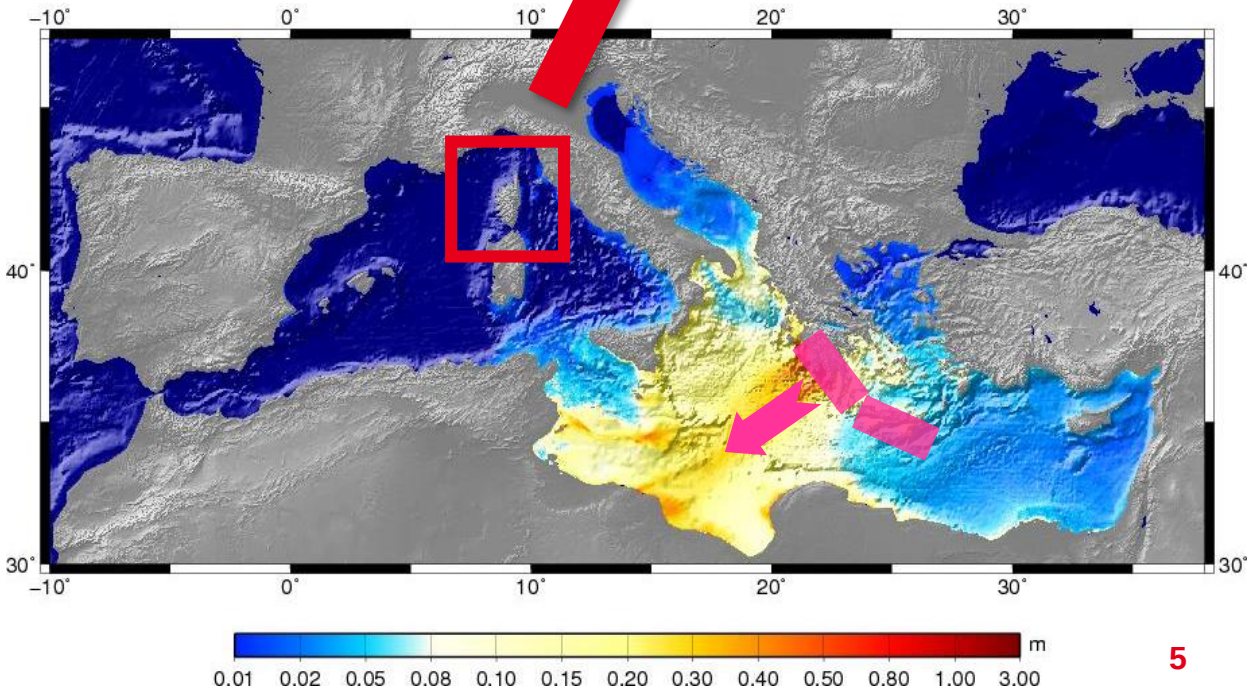
- For M>8, major impact in the eastern basin
  - Including Middle East and North Africa
- Refined HR modeling → Impact in eastern Corsica











Gailler et al., 2016

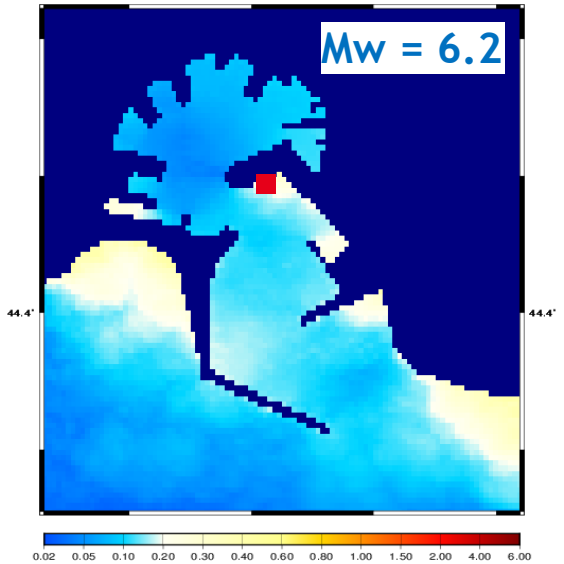
1887 tsunami in Ligurian Sea

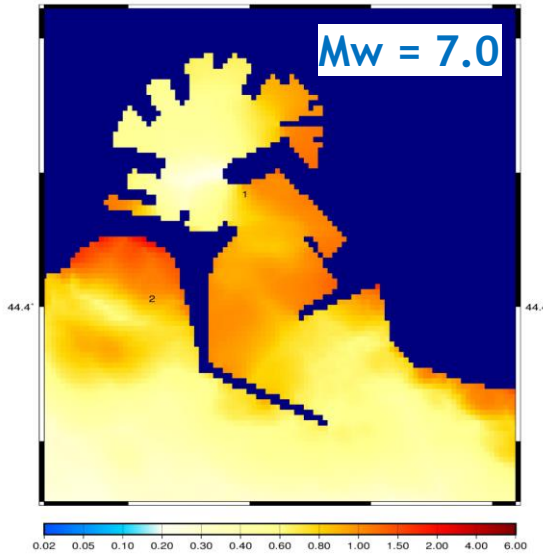
Significant tsunami in the Ligurian Sea

- Original magnitude estimated 6.2-6.5
- A historical tide gauge record known in the literature (Eva and Rabinovich, 1997)

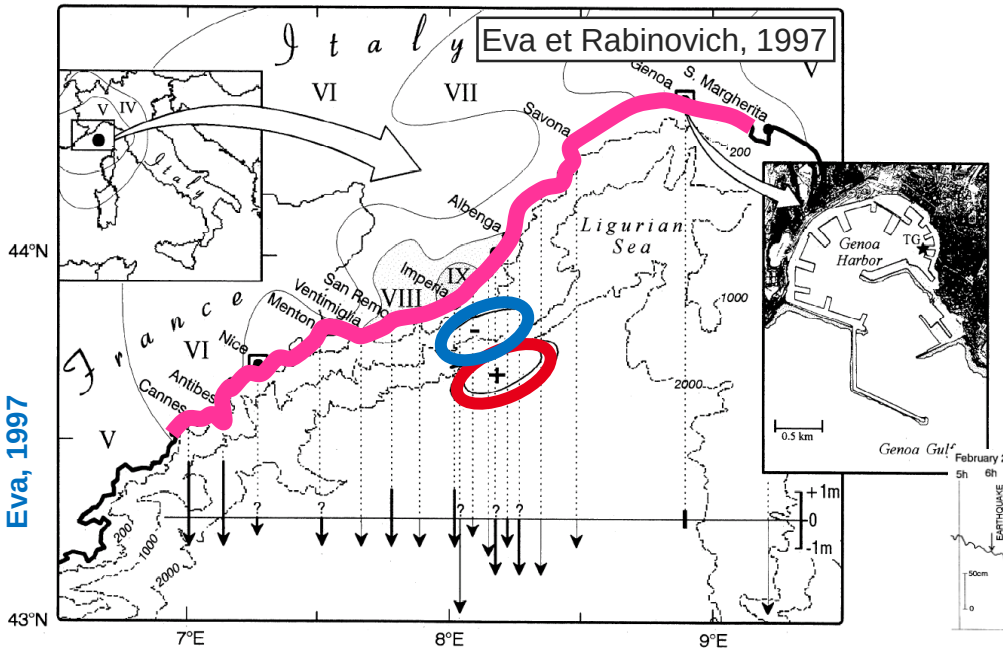
Work on the **original tide gauge** record in Genoa

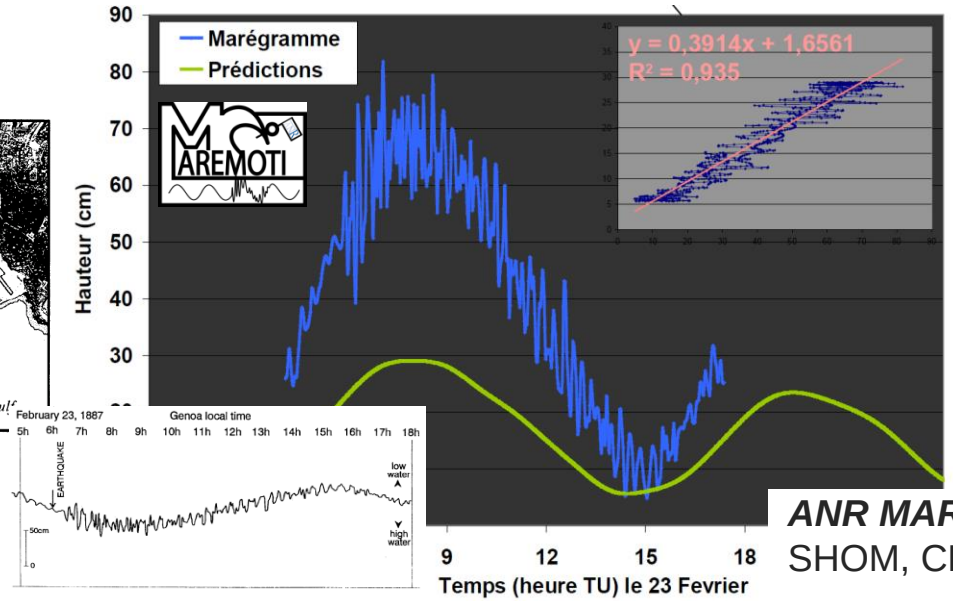
- Correction of the amplitiude when comparing with theoretical tide (factor ~2.5)
- But model not consistent for various harbours

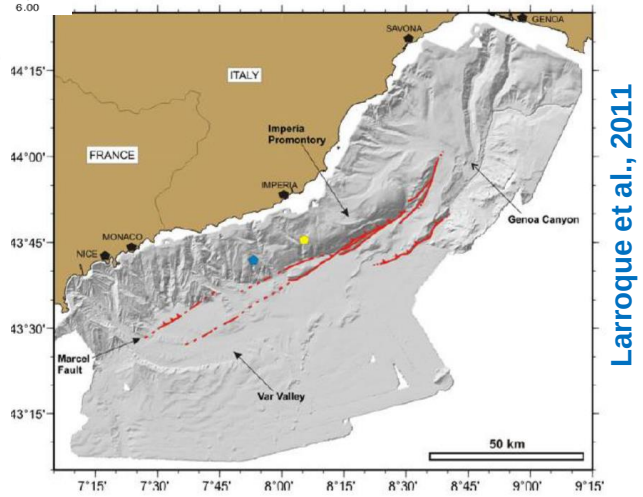




Testing various thrustiing mechanisms







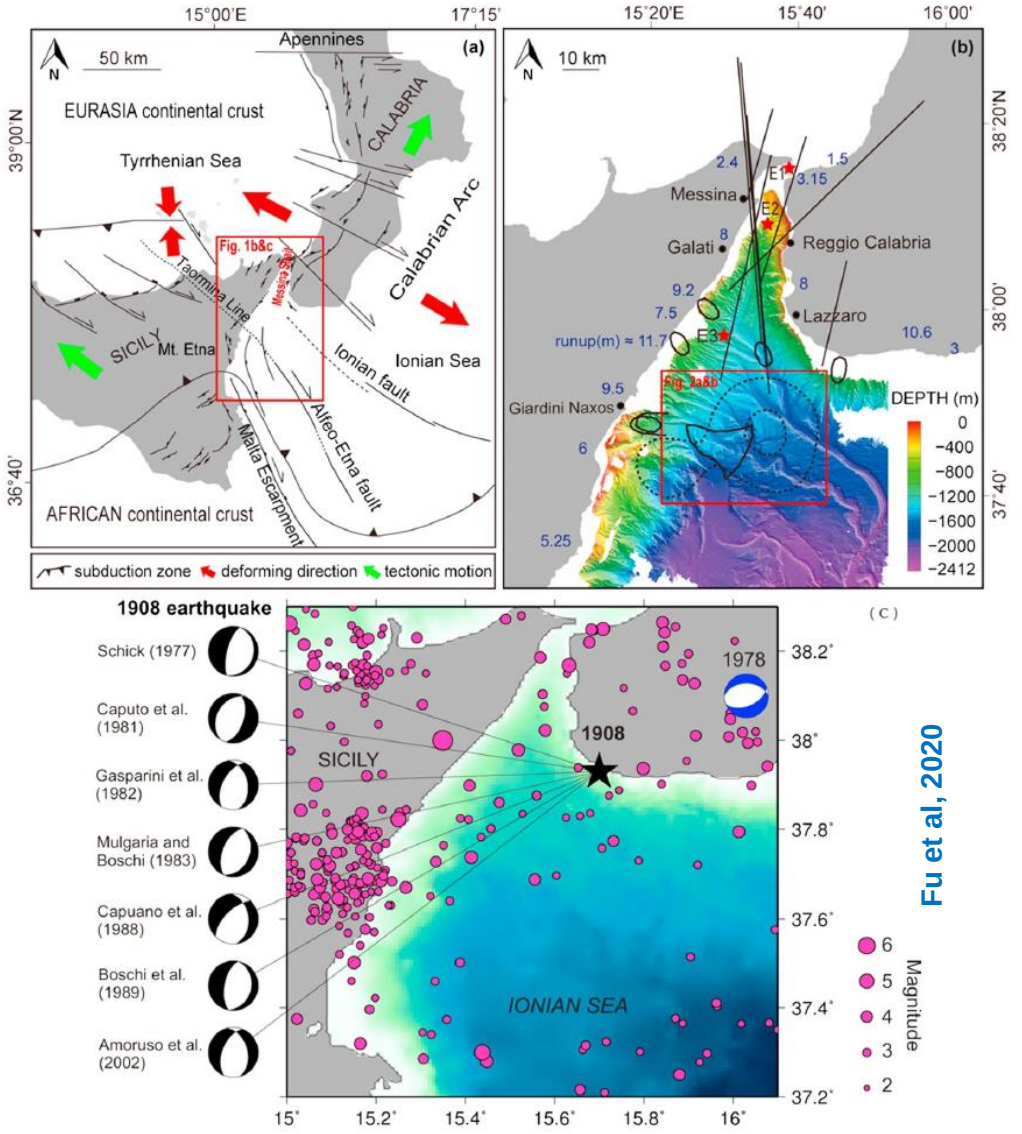
Larroque et al., 2011

ANR MAREMOTI project

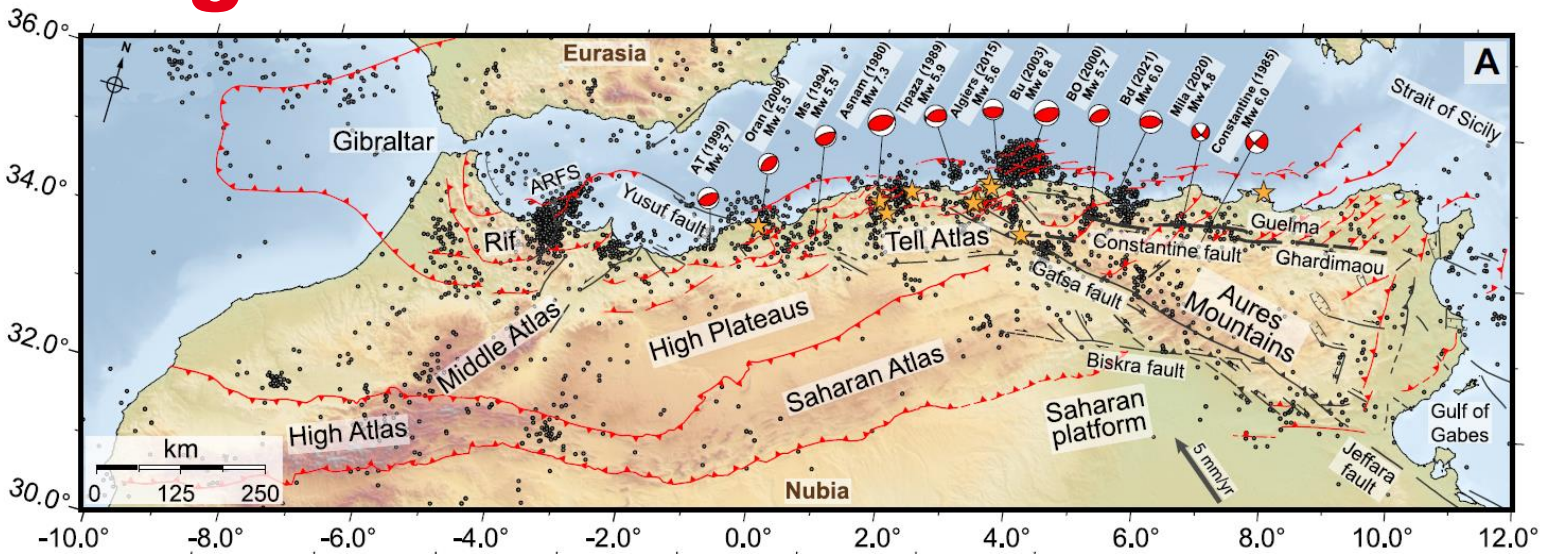
SHOM, CEA – Monnier et al., EGU 2017

From East to Central Mediterranean

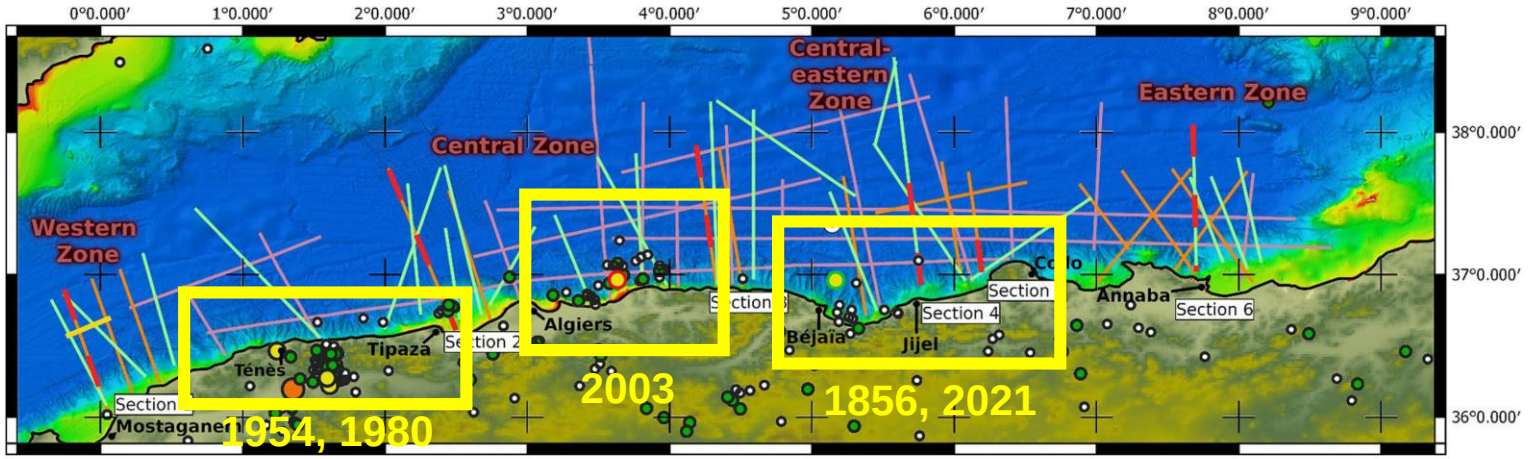
- **1908**: One of the most recent catastrophic Mediterranean earthquake and tsunami
- Complex tectonic pattern
  - Additional landsliding?
- Challenging near field context



North Algerian margin



Viltres et al., 2025



Leffondré et al., 2021

Spiral Seismic sections
Industrial seismic sections
Seismic sections shown in the article
Older seismic sections

Additional locations :
DSDP 371
Boumerdès epicenter 2003
Bejaia epicenter, March 18, 2021

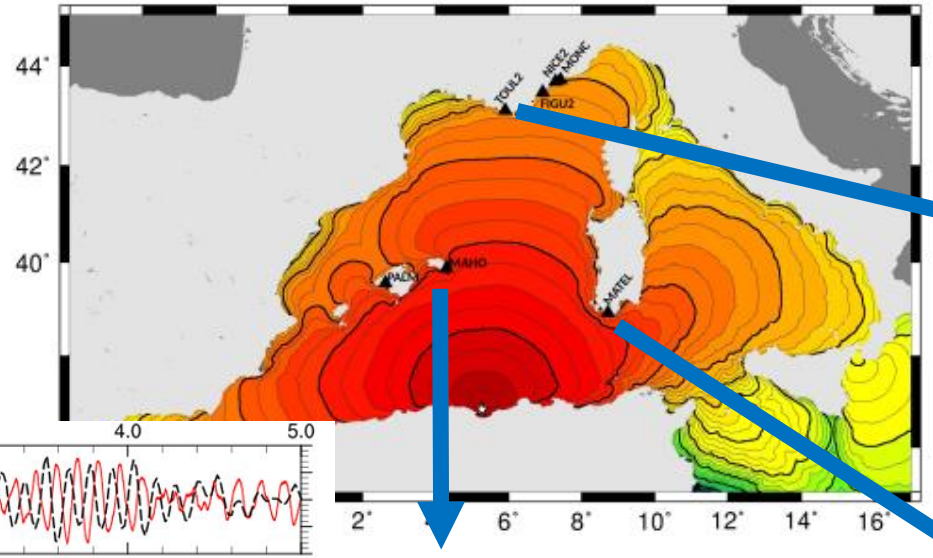
Bathymetry : 5 m, 40 m, 200 m, 500 m, 3000m

Topography : 0 m, 500 m, 1000m, 2000m, 3000m

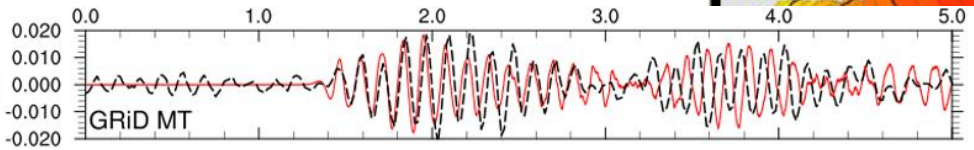
Magnitude scale :
4,5 to 4.9
5 to 5,9
6 to 6.9
7 and more

Tsunami observations on March 18, 2021

- Earthquake in North Algeria, 18 March 2021
- Mw = 6.0

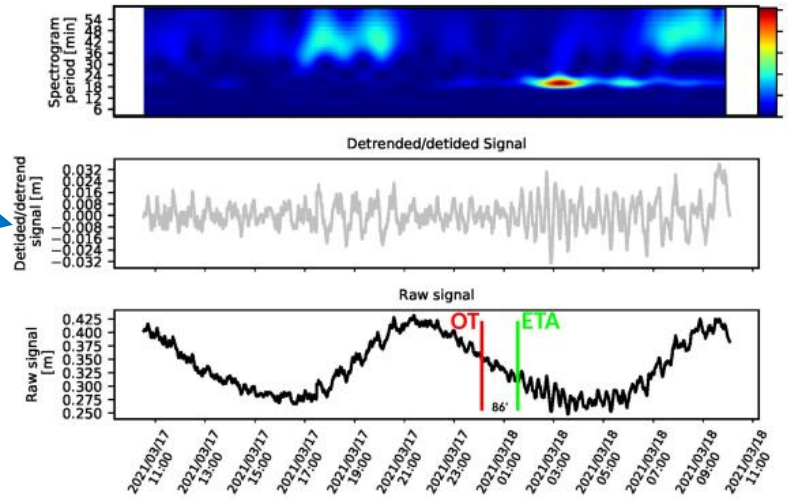


March 18, 2021, Nice harbour tide gauge signal and model

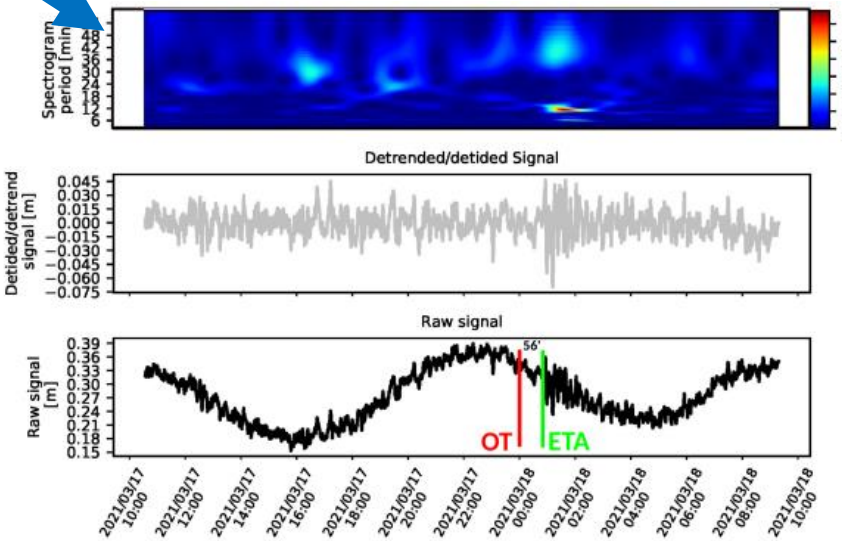


Heinrich et al., 2024

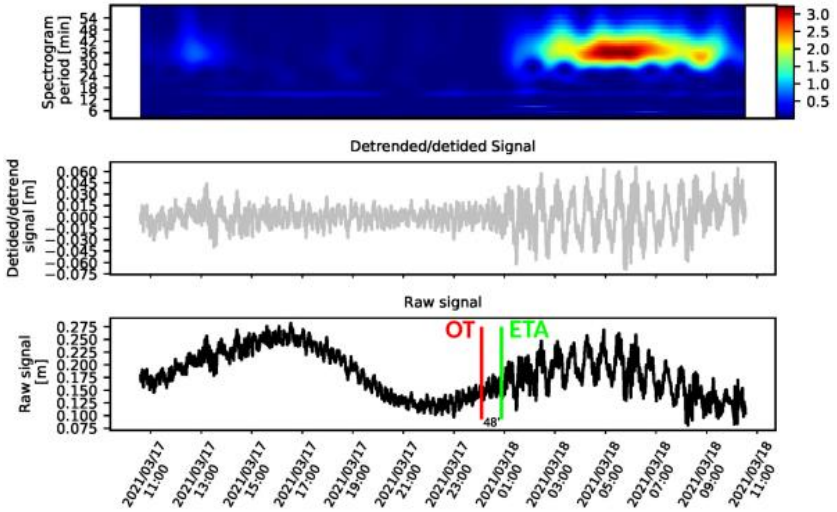
Toulon ~ 5 cm

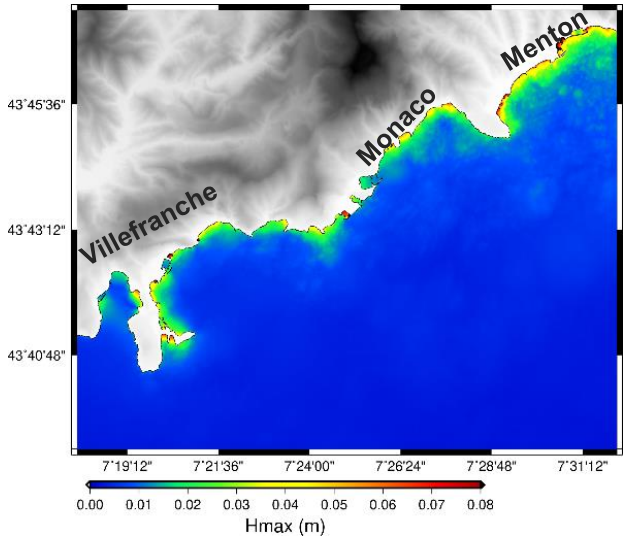


Marina di Teulada ~ 9 cm



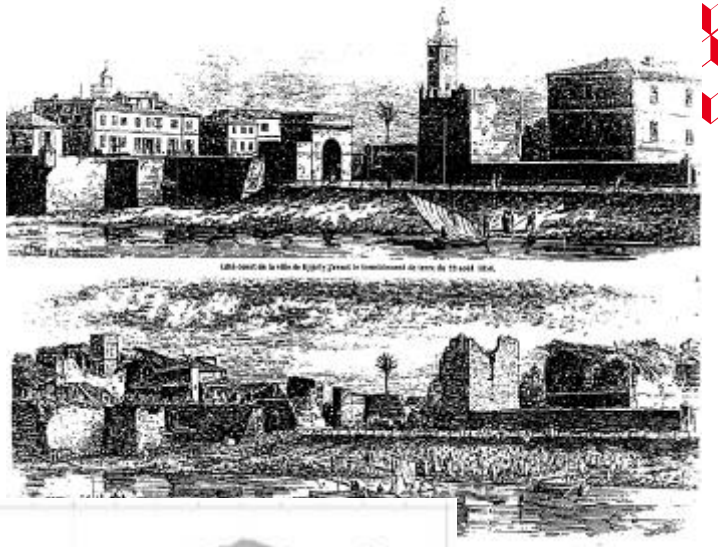
Mahon ~ 6 cm (crest-to-trough)



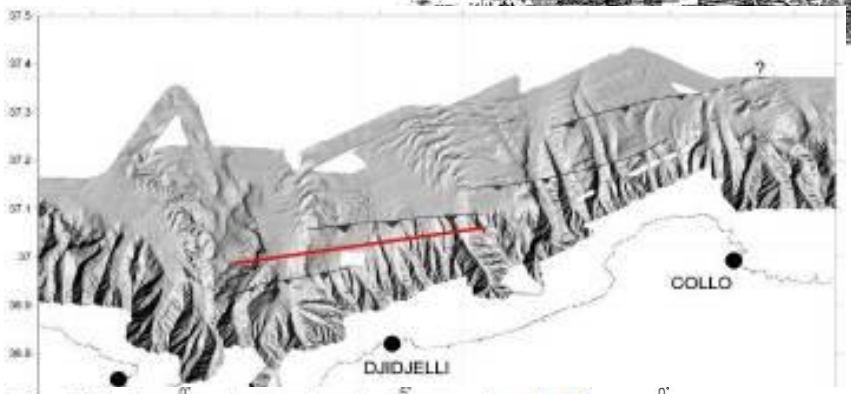


1856, Jijel

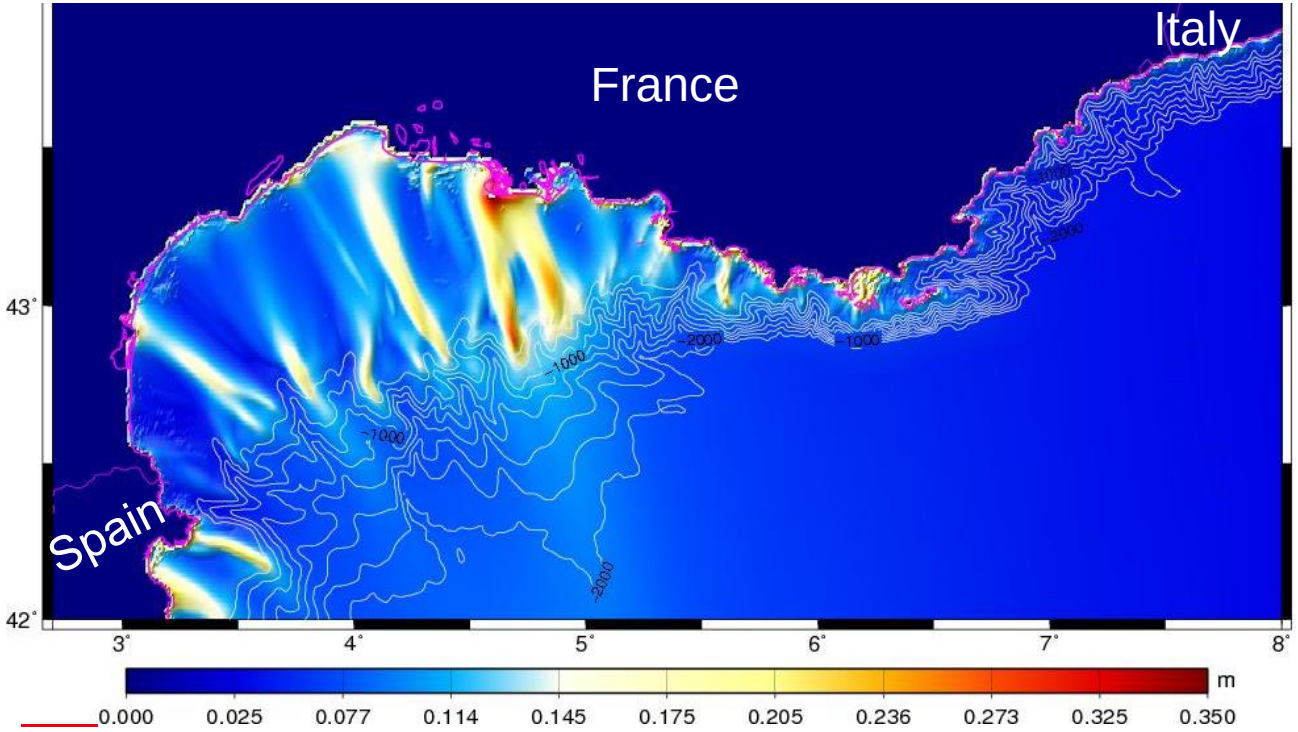
- Widely felt, with two mainshocks possibly occurred, M ~7.2 ?
- Coastal flooding reported
  - Severe weather conditions made testimonies difficult
- Coastal impact ~1 m possible in Spain, France

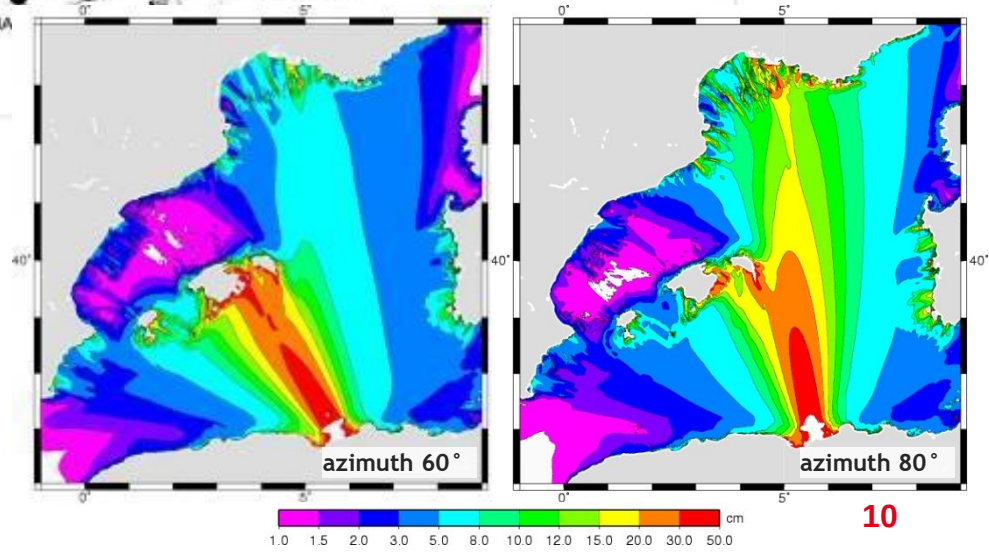


Yelles, 1991



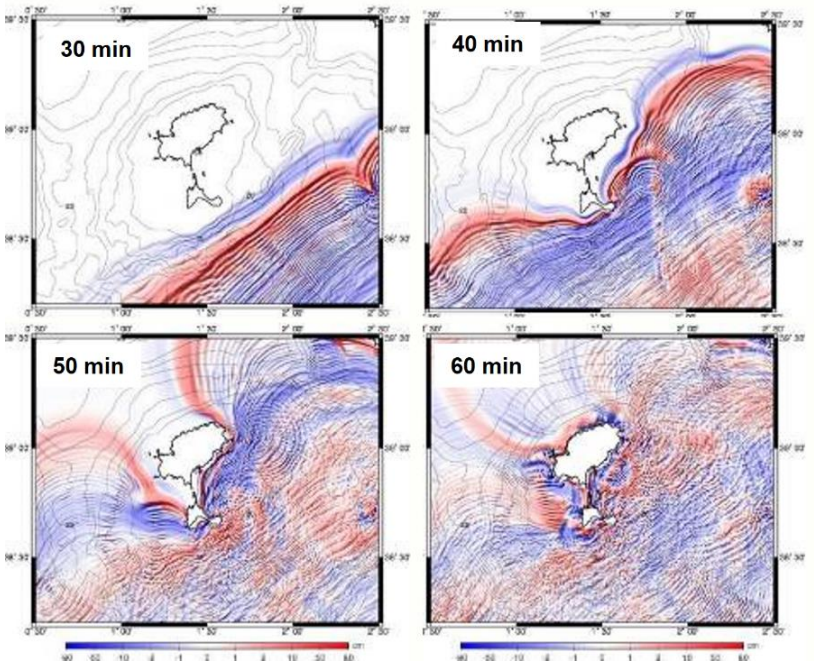
Domzig, 2006

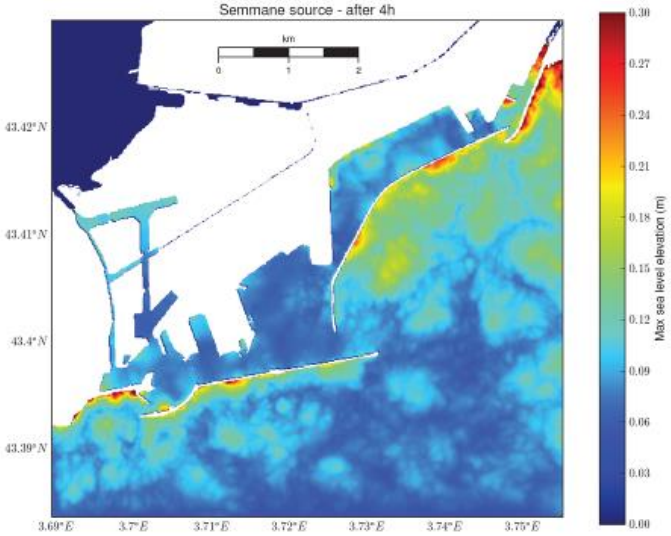


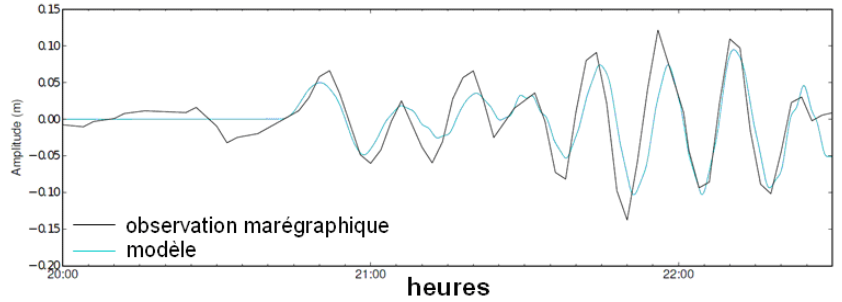


Boumerdès, 2003

- Mw ~ 6.9



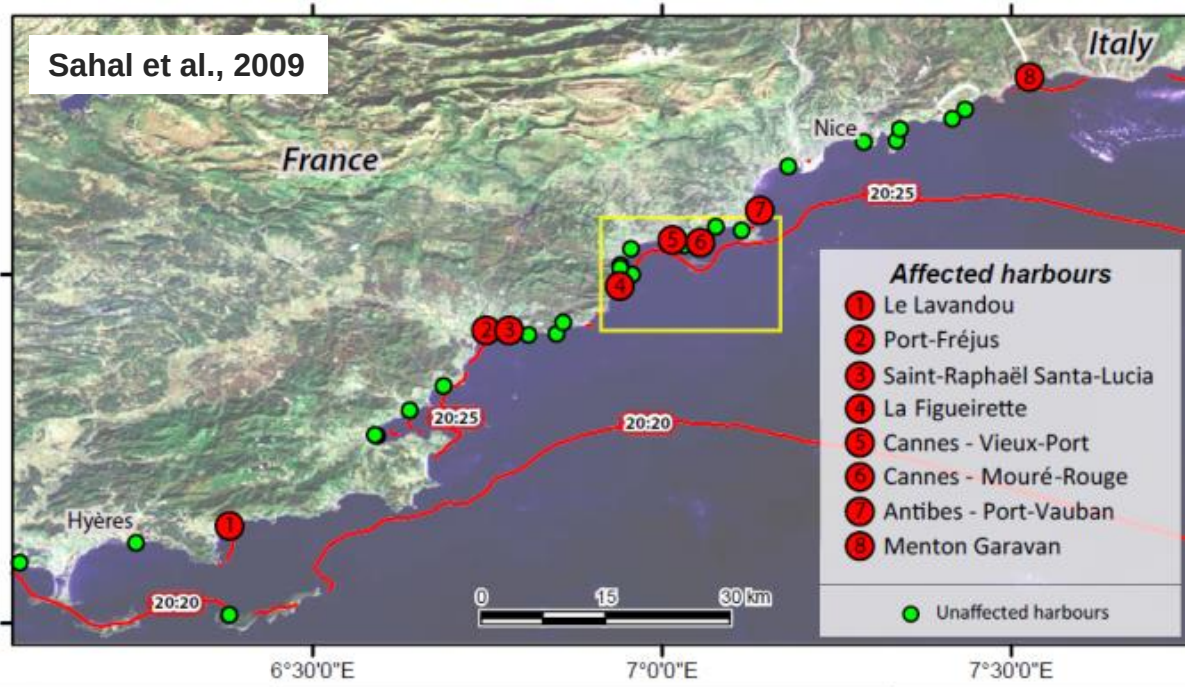




Tsunami observation and model in Sète harbour

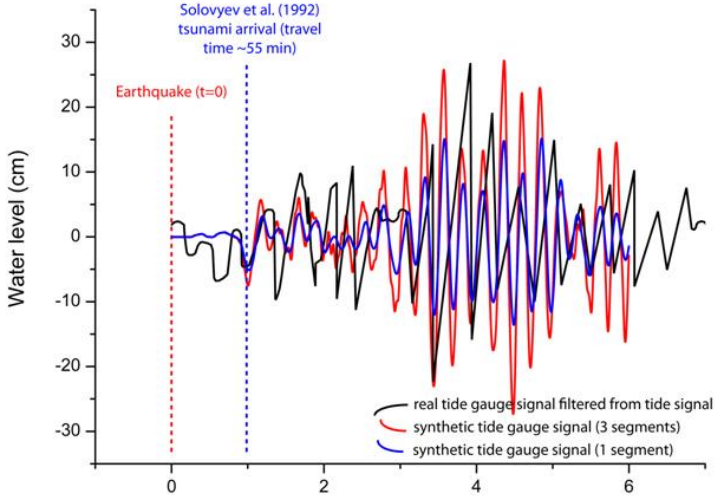
Palma (Majorca)

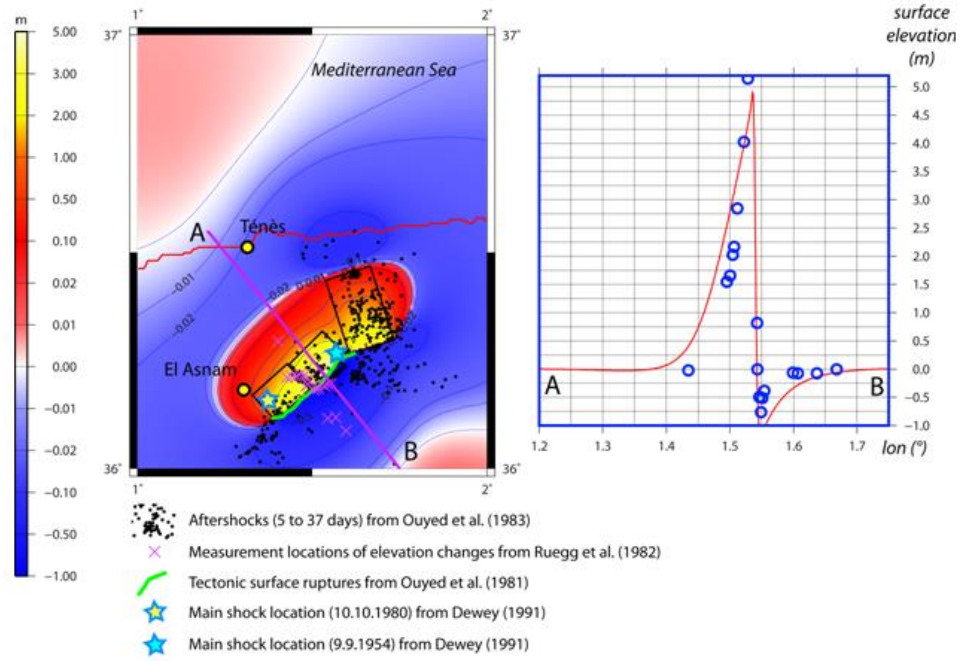
Le Lavandou



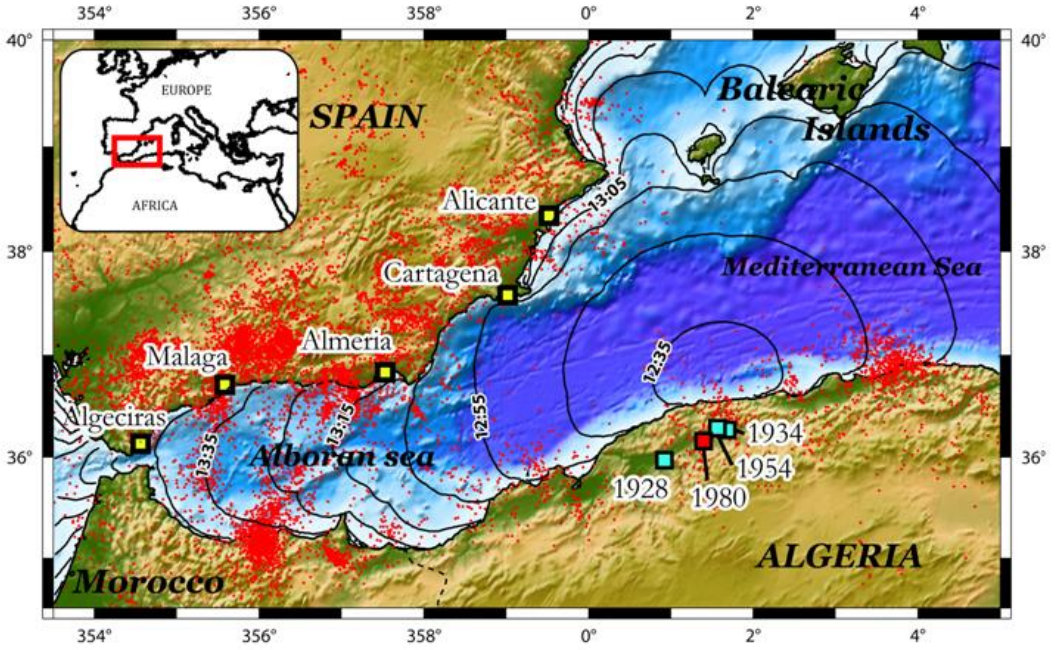
1980, El Asnam

- Ms 7.3, thrust mechanism
- Modeling of tide gauges in Spain
  - Results consistent with a coseismic triggering, without turbidity flows mentioned in the 1980s
- Tsunami triggering from inland ruptures

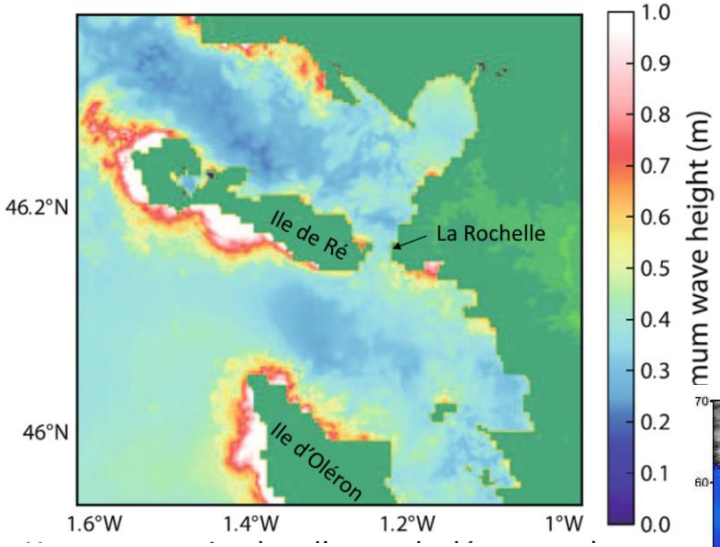




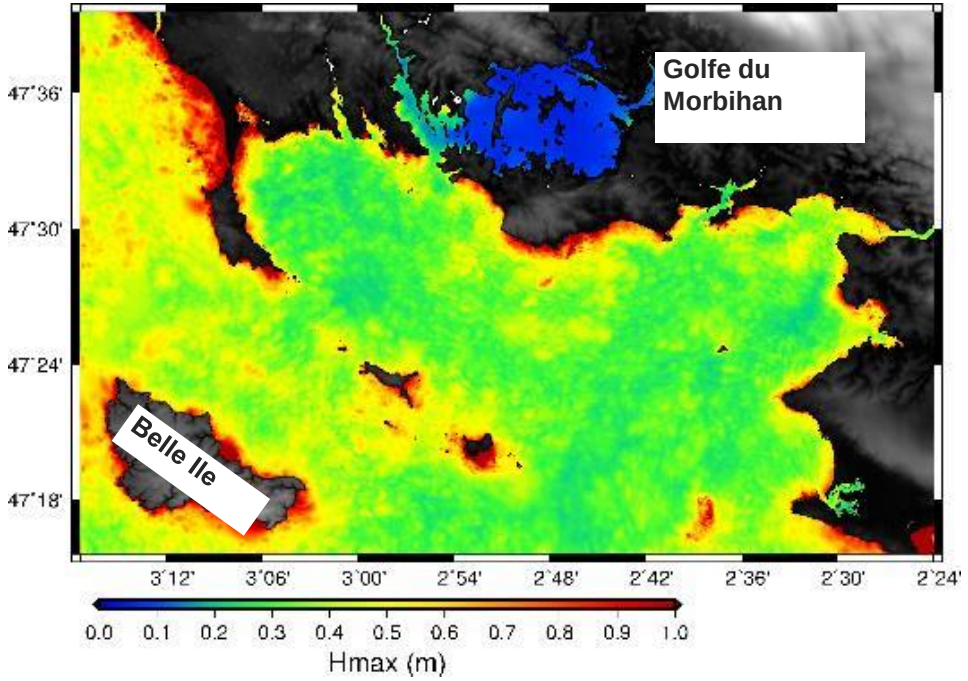
Roger et al., 2011



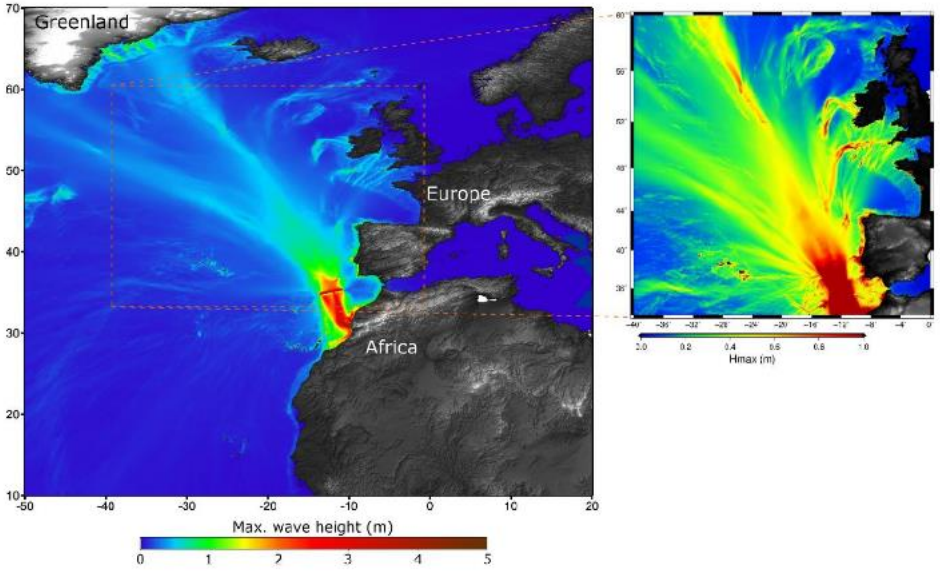
1755 tsunami



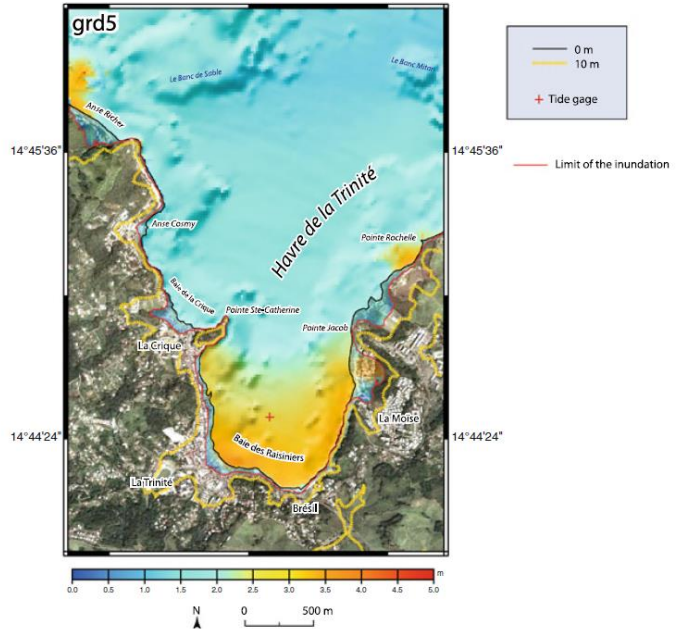
Allgeyer et al., 2012



Roger et al., 2010



La Trinité, Martinique



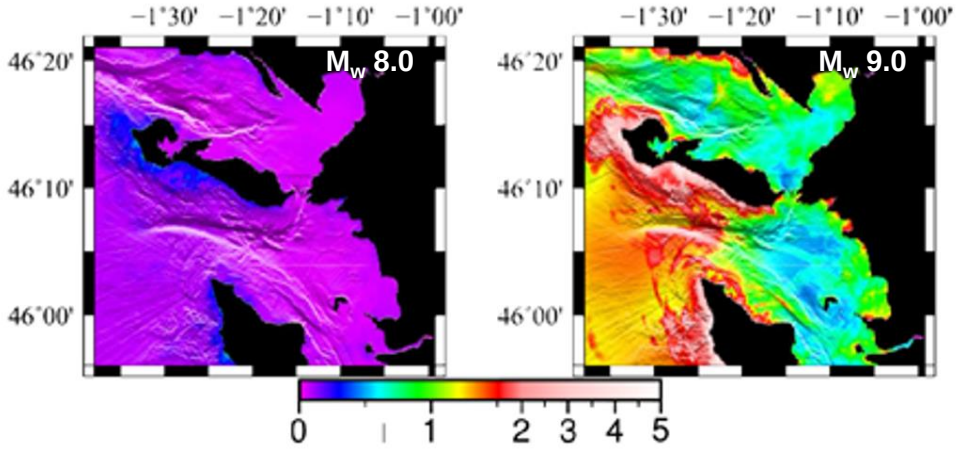
Source Baptista et al., 2003

NEAMWave23 Exercise (IPMA, Cenalt)

Sources in the Caribbean SZ

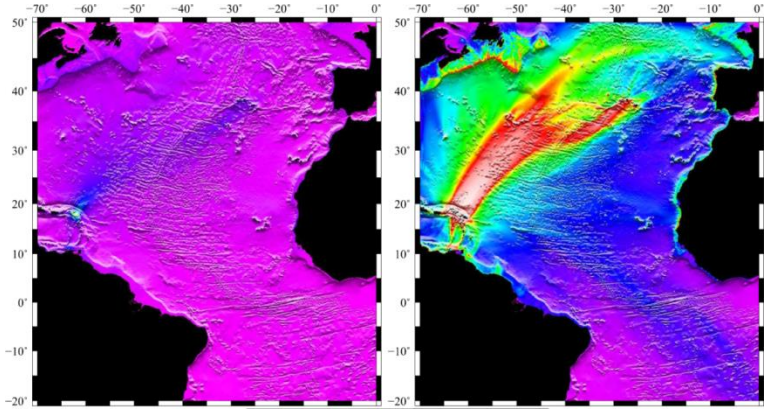
Sources in the West Indies

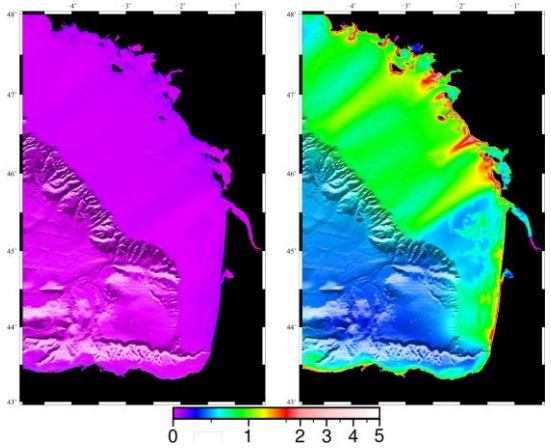
- Models towards Europe (M_w 8.6) (Roger et al 2014)
- Scenarios with M_w 8.0 and M_w 9.0

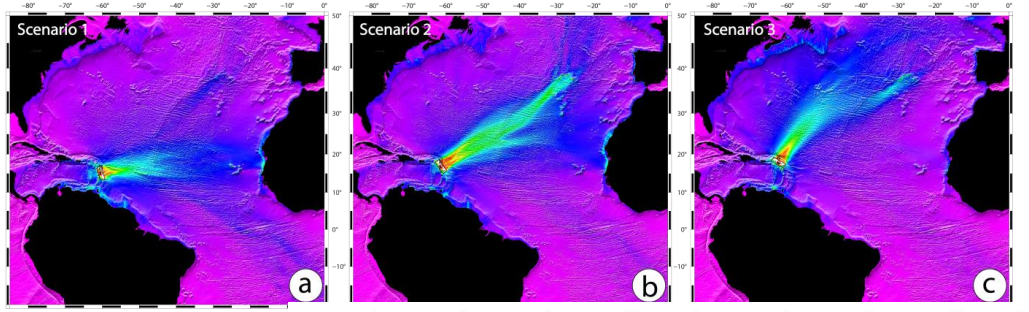


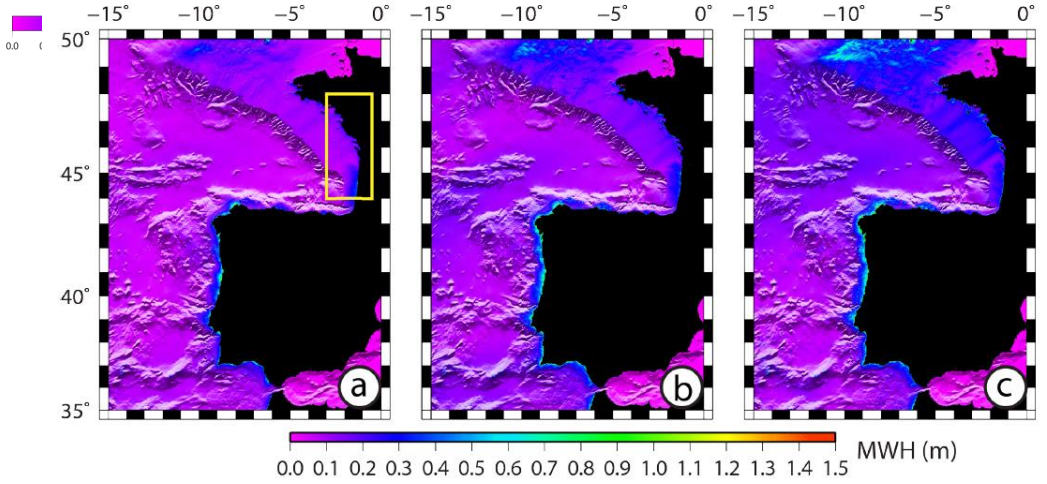
Frere, 2016

Source	Lon (°)	Lat (°)	Depth (Km)	Slip (m)	Strike (°)	Dip (°)	Rake (°)	Length (Km)	Width (Km)	Rigidity ($N.m^{-2}$)	M_W
4	−62.3	17.8	35	3	120	26	90	200	80	30×10^9	8.0
5	−62.3	17.8	35	15	120	26	90	500	150	30×10^9	9.0



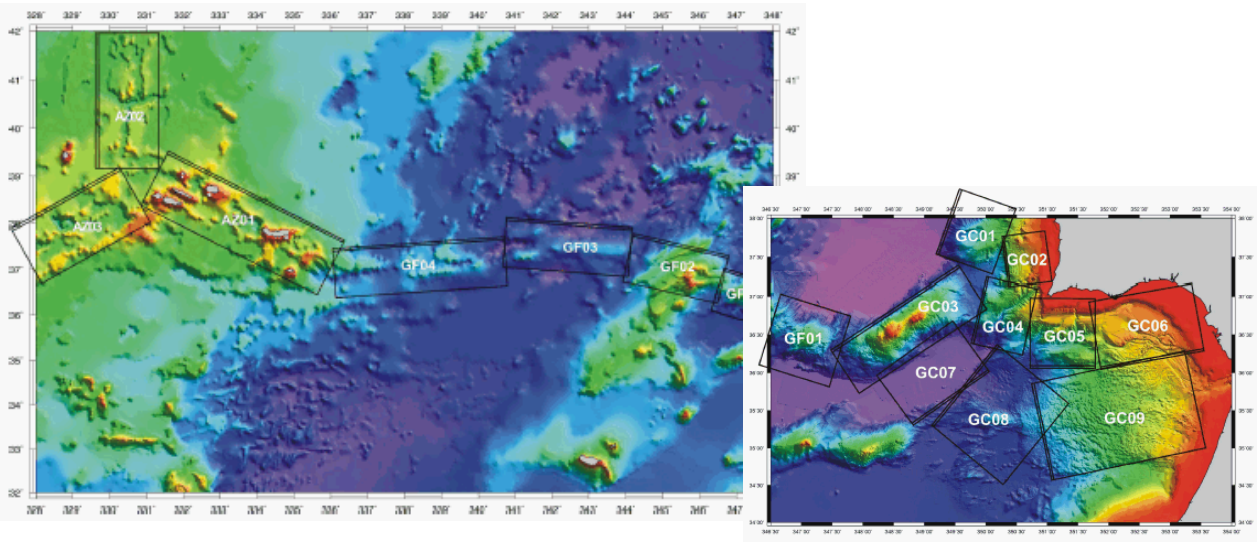




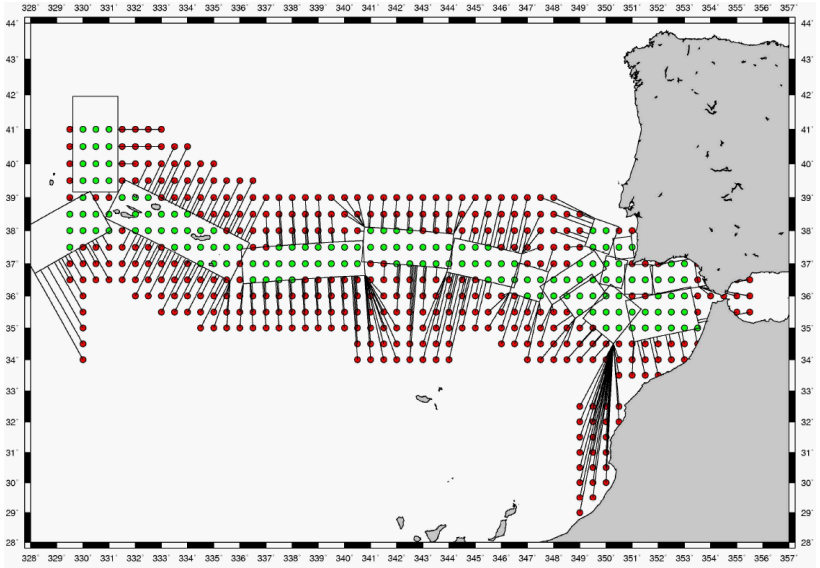


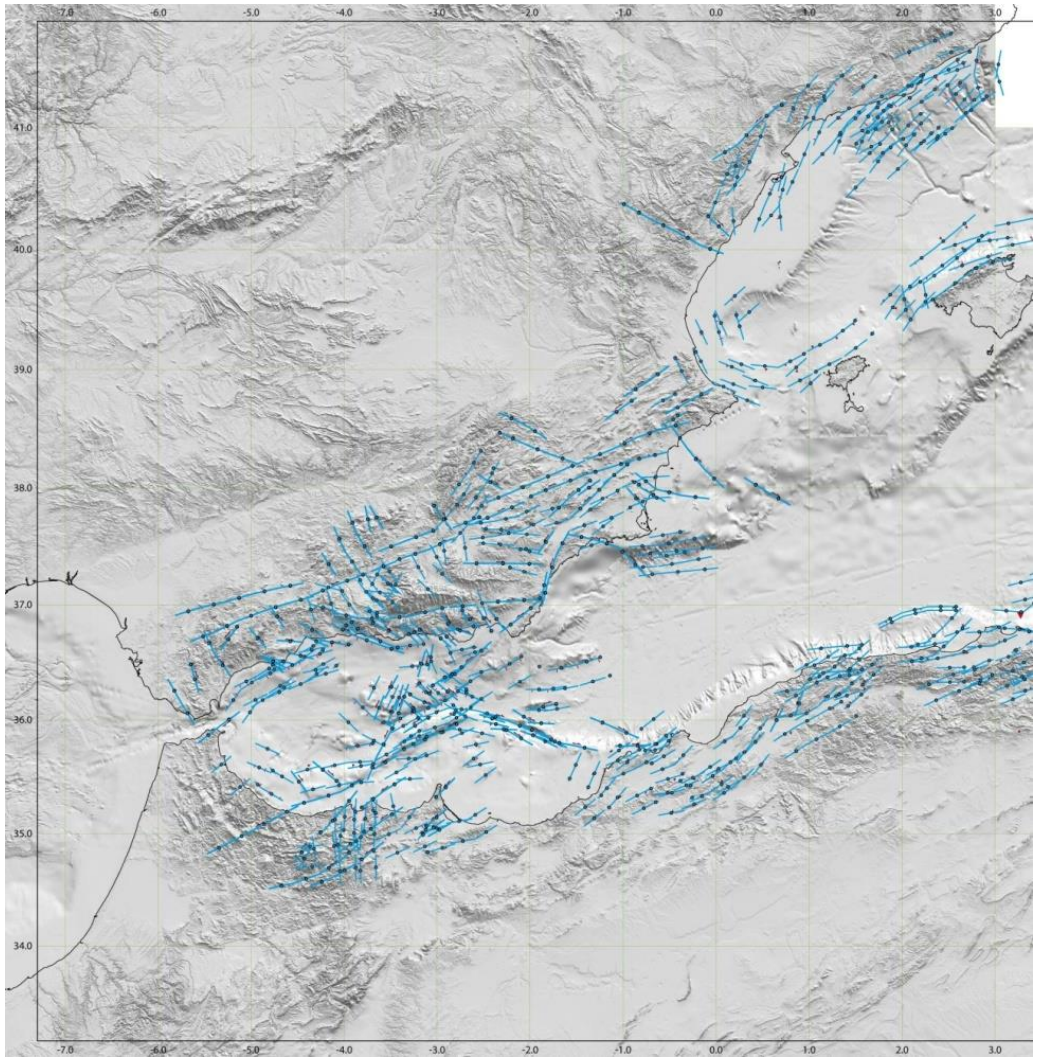
Roger et al., 2014

Fault databases



Fault database in IPMA from JRC



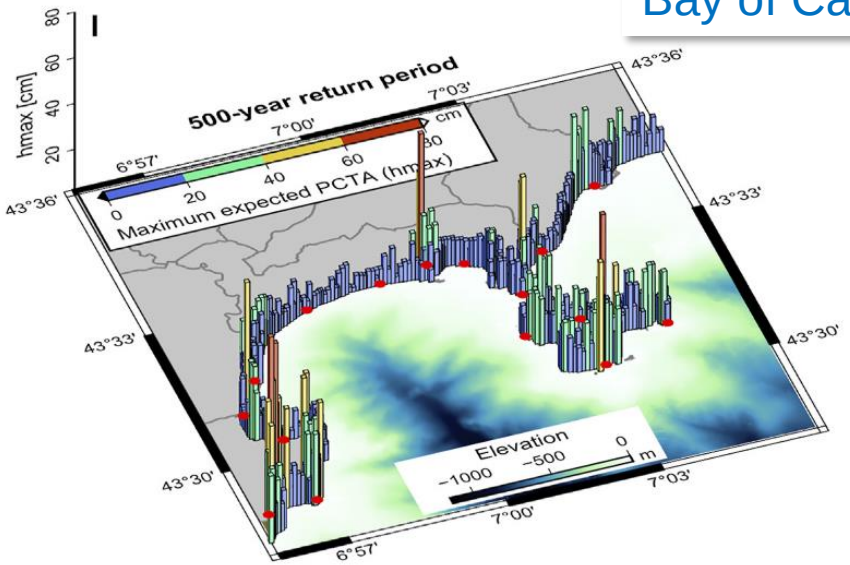


Unit fault database in Cenalt

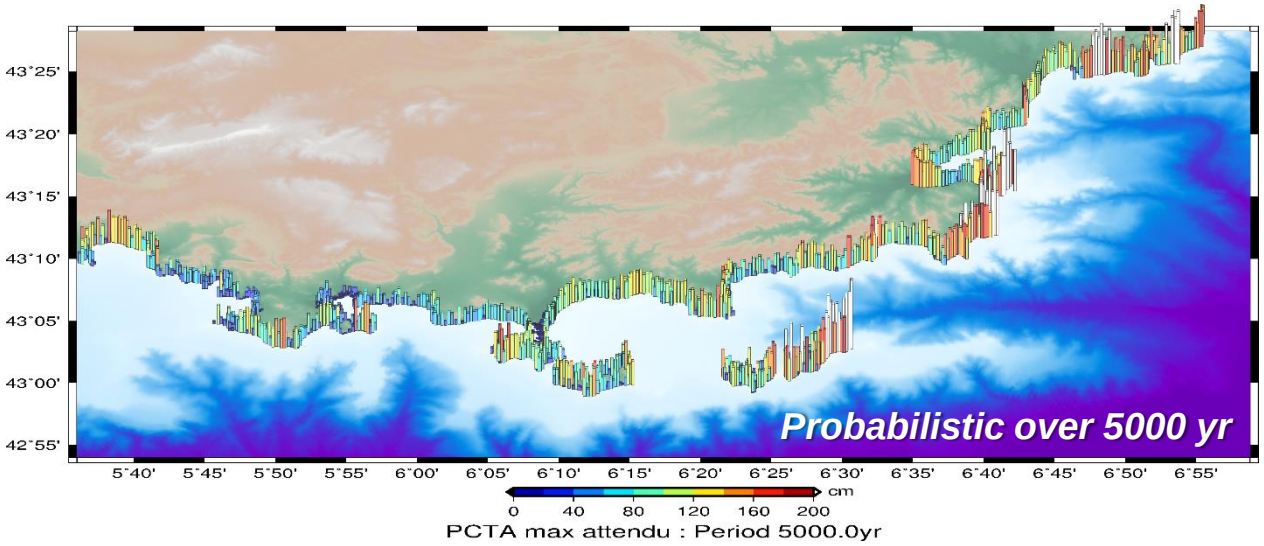
Probabilistic Tsunami Hazard Assessment

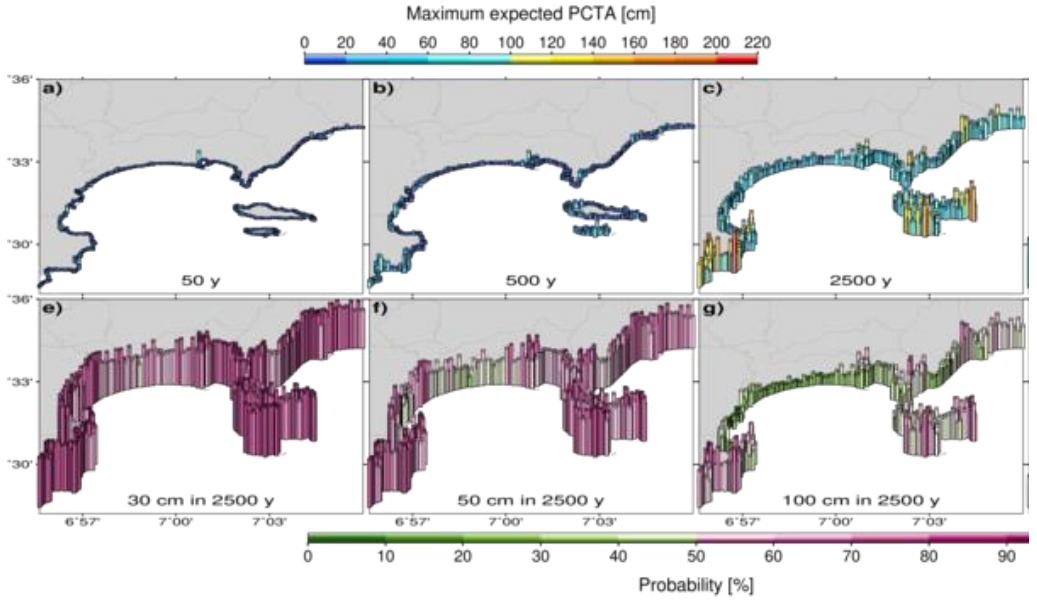
- Seismic catalogue with Gutenberg Richter analysis
- Including coastal HR modeling
- Results in terms of
  - Return periods
  - Peak Coastal Tsunami Amplitude

Bay of Cannes



Souty and Gailler (2021)

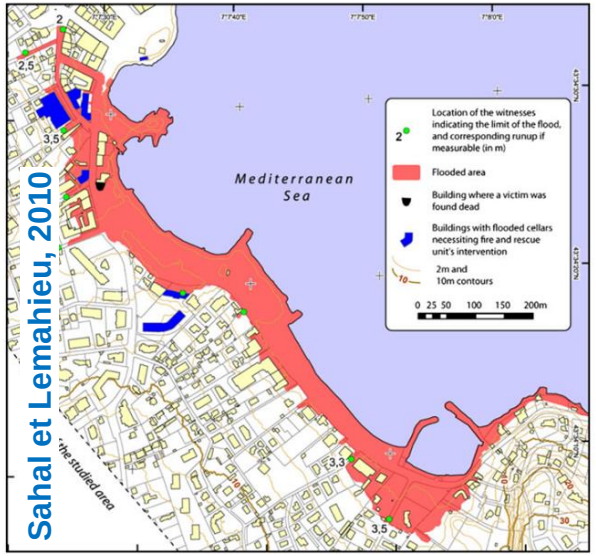


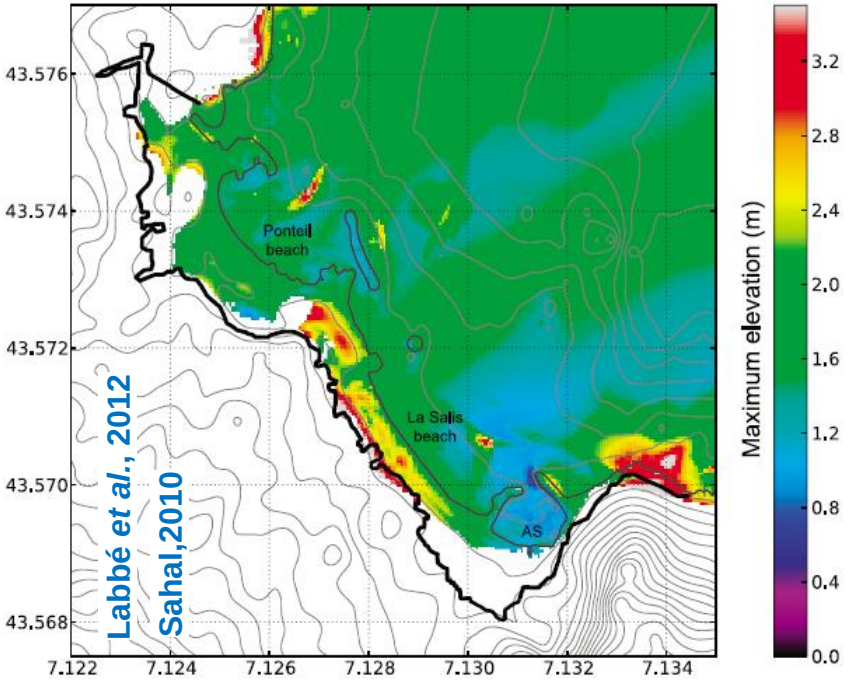


Nice airport landslide and tsunami, 1979

Landslide off the Nice airport in 1979, without any earthquake

- Slide rheology characterized in detail with various viscosities, with volume increase during the slide
- Model of observations in Antibes (run-up 3 m)





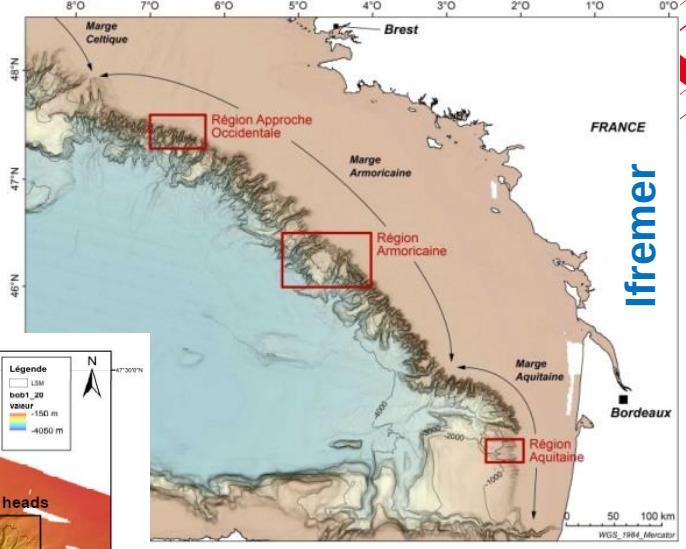
Major landslides in the Atlantic?

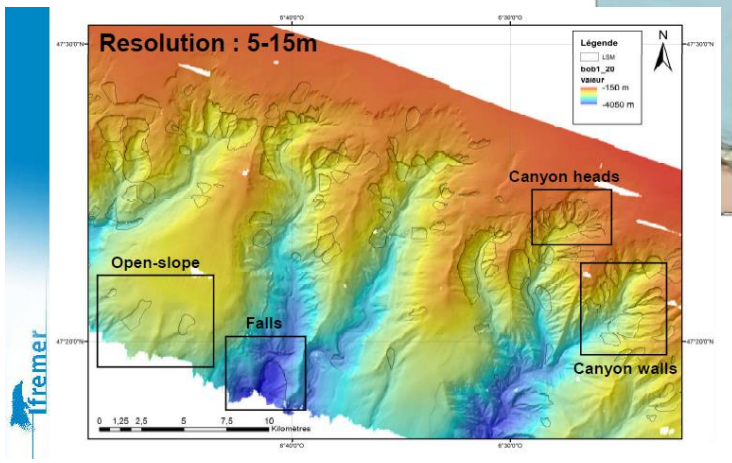
Sedimentological characterization close to the scars (Ifremer)

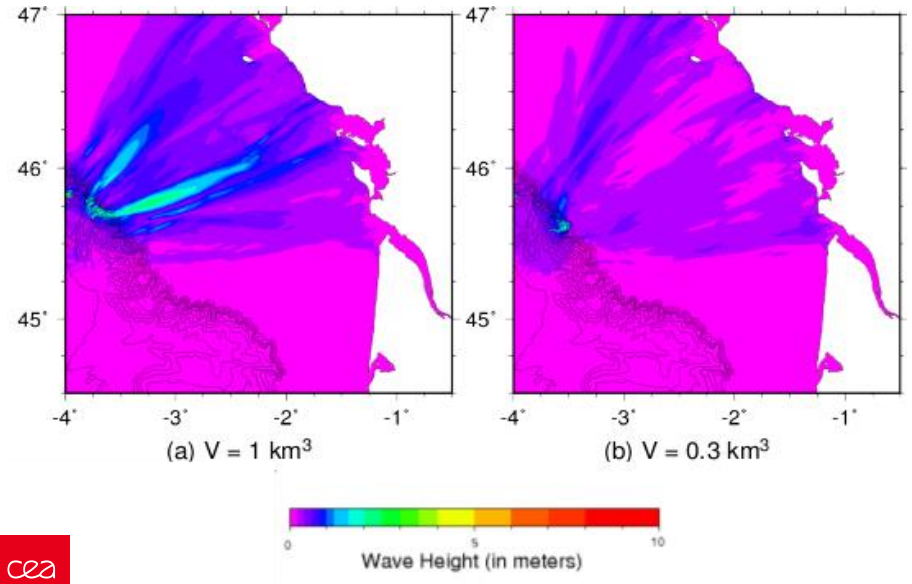
- High resolution seismics
- How sea level rise can effect stress conditions?

Modeling of the sliding processes

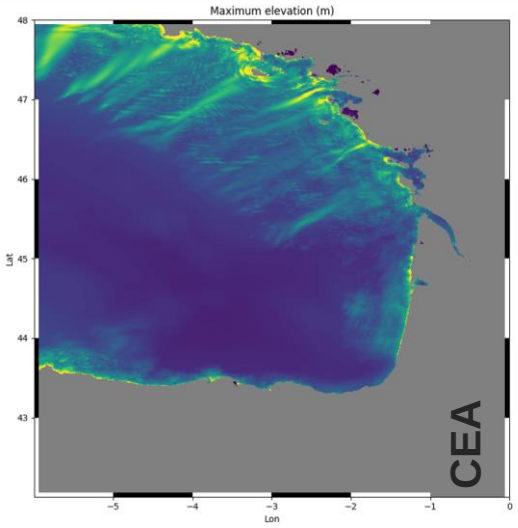
- Regional sources on the margin
- Distant sources: Canaries (below, 80 km^3)
  - Return periods > 10^4 -10^5 yrs

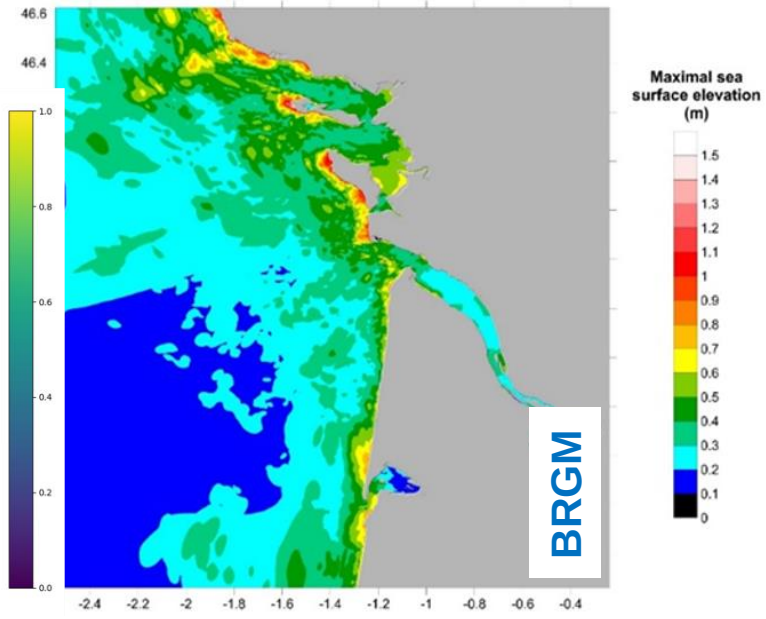






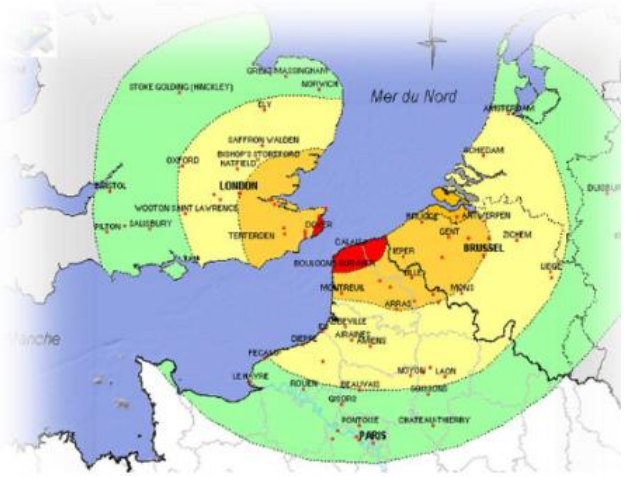
Frère, 2016





Lessons to be learned

- Many tsunamigenic sources remain **poorly characterized** in terms of seismotectonics
- **Observed tsunamis** can help to derive and discuss some source mechanisms thanks to modeling
  - Using tsunami model with HR bathymetry
  - Even for small tsunamis
  - Direct models are not unique
- **Future scenarios** can be based on past events and available seismotectonics parametrization
  - However this is usually not enough to capture extreme events
- **Probabilistic approaches** can help to explore a wider set of scenarios
- **Landsliding sources**
  - Including postseismic slides
  - Role of sea level rise?
- **Continuing effort** needed to explore submarine tectonic structures



Dover earthquake, 1580

Thank you for attention