Seismotectonics of tsunamigenic earthquakes in the Mediterranean Sea and connected seas

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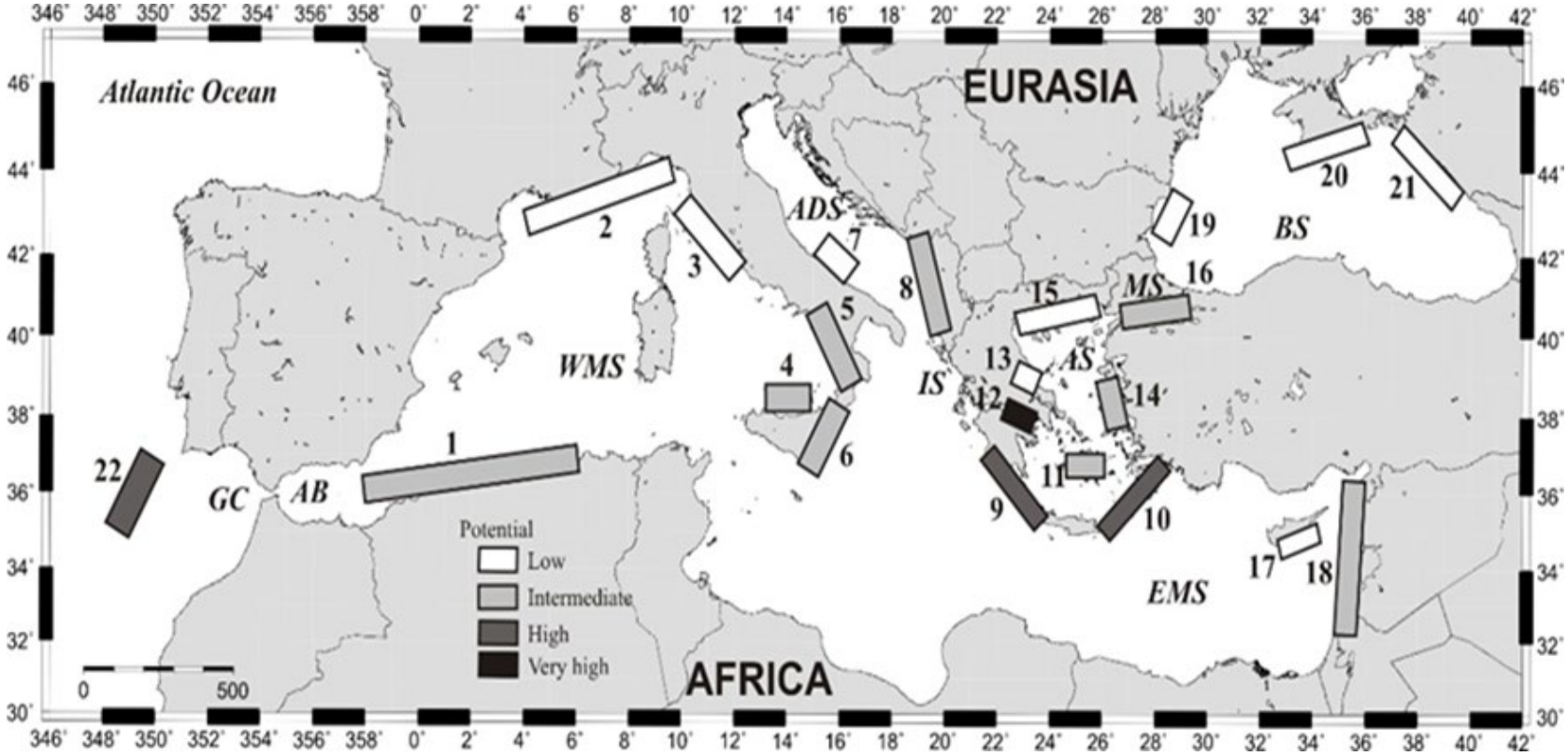
Objective of the presentation

- To investigate the link between seismotectonics and generation of seismic tsunamis in the study region.
- More specifically we aim to investigate:

- the minimum magnitude and the maximum focal depth for tsunami generation, and
- the focal mechanisms of earthquakes that produce tsunamis.

Main tsunamigenic zones
(historical, archaeological & geological evidence)



Papadopoulos et al. 2014

Earthquake data

Earthquake catalogues

- Time period 1900-2020
- ISC-GEM
- SHEEC (SHARE, 2013)
- GCMT project
- Initial selection for $M_w \geq 6.5$
- Allowing for epicentral errors finally we considered $M_w \geq 6.45$ regardless focal depth, h.
- Submarine and coastal earthquakes (epicentral distance of ≤30 km from closest coast) have been taken into account.

Final earthquake selection

- 66 earthquakes selected
- M_w range: 6.45 to 7.84
- h range: 10 km to 95 km.

Tsunami data

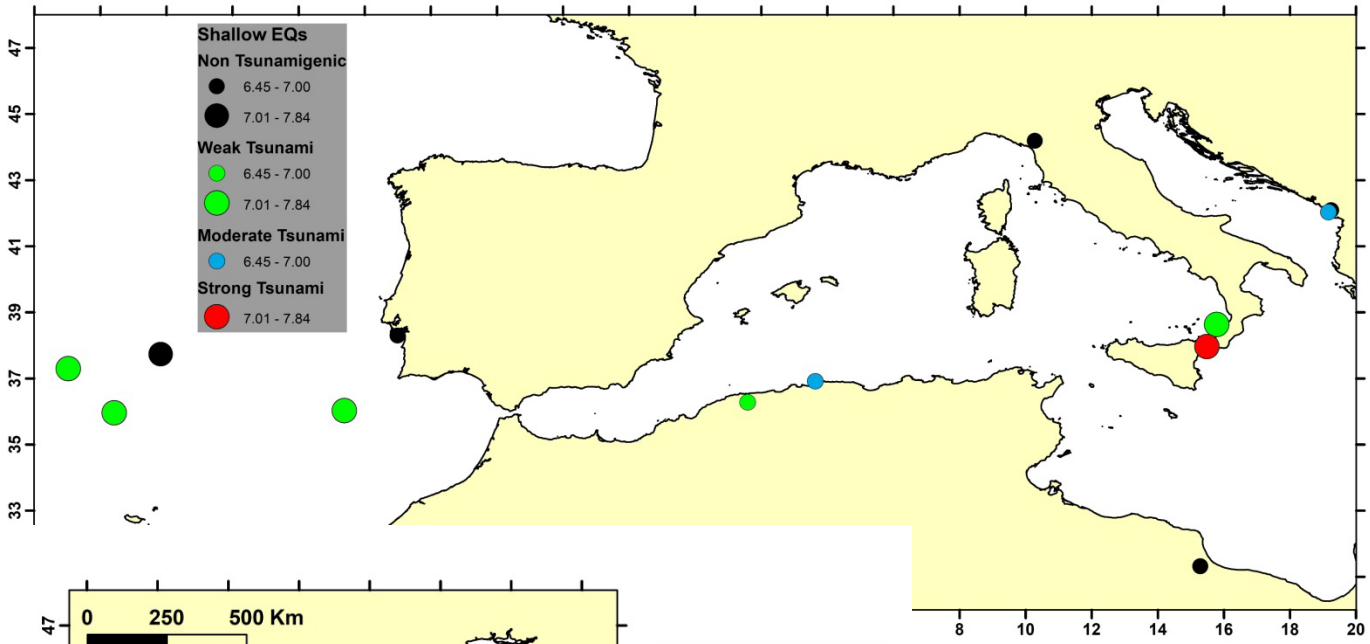
Tsunami catalogues

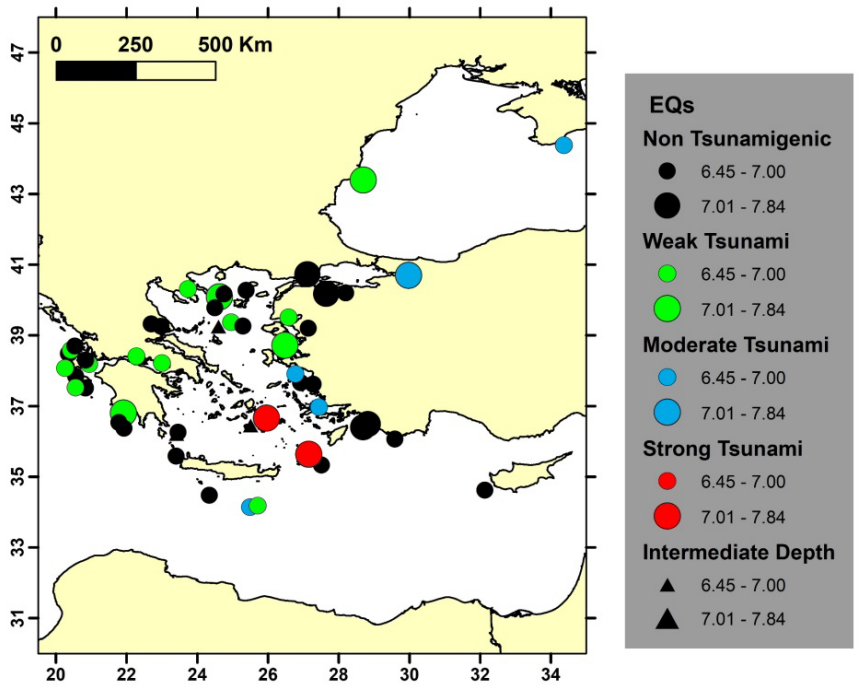
- Time period 1900-2020
- An updated catalogue was compiled based on previous catalogues (Maramai et al., 2014 , Papadopoulos et al., 2014) and on recent data (2015-2020) from several publications.

Final tsunami selection

- Only “remarkable tsunamis”, i.e. of
- Intensity K≥3 in the 12-grade Papadopoulos-Imamura scale, or
- wave height h≥30 cm, or
- recorded by at least 3 tide-gauges.
- Only “reliable tsunamis” of R= 3 or 4 in a reliability index R from 1 to 4
- A relative severity was introduced: weak tsunamis (19), moderate tsunamis (7), strong tsunamis (3).
- Finally, 29 tsunamis were selected.

Tsunamigenic and non-tsunamigenic EQs





Epicenter distribution of tsunamigenic EQs (coloured circles) and of non-tsunamigenic EQs (black circles).

The overall rate of tsunamigenic earthquakes, regardless magnitude and focal depth is **29:66=0.44.**

Rate of tsunamigenic earthquakes

According to magnitude

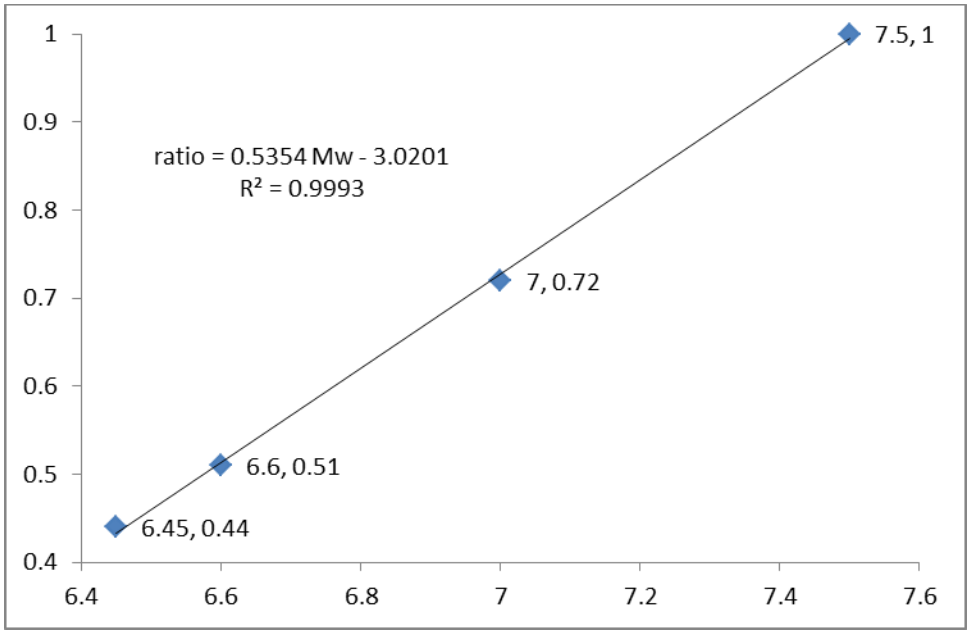
- Tsunamis were produced by earthquakes in the entire magnitude range considered: M_w from 6.45 to 7.84.
- 29 tsunamigenic earthquakes were classified as follows:

  -$M \geq 6.45$

  -$M \geq 6.60$

  -$M \geq 7.00$

  -$M \geq 7.50$
- There is a clear linear increase of the tsunamigenic ratio with the increase of the earthquake magnitude.



Rate of tsunamigenic earthquakes

According to focal depth

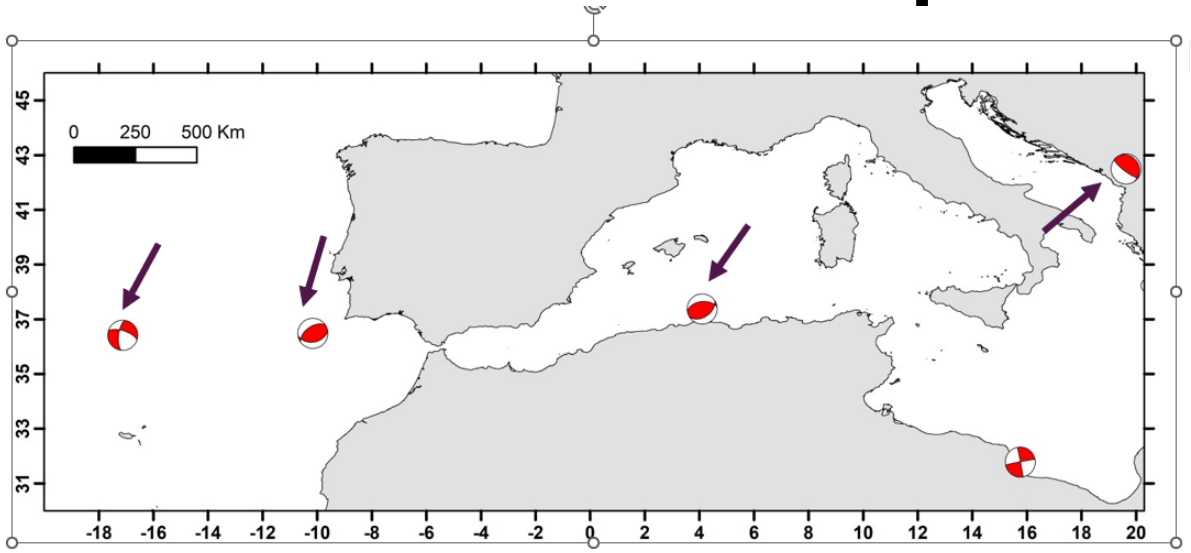
- The focal depth, h, of 66 earthquakes ranges **from 10 km to 95 km** but the uncertainty is higher for the early period examined (before 1965).
- Nearly all tsunamis were produced by earthquakes of $h \leq 20$ km, **only one** earthquake was of h=35 km.
- For $h \leq 20$ km the ratio of tsunami generation is **28:66=0.42**.

Seismotectonics of tsunamigenic earthquakes

Focal mechanism data

- The catalogue ISC-GEM (2024) was used.
- This catalogue lists strike/dip/rake for **35 out of the 66** selected earthquakes starting from 1935 but systematically from 1968.
- Data sources of ISC-GEM are the GCMT project and other sources for earlier periods.

Seismotectonic style of tsunamigenic earthquakes

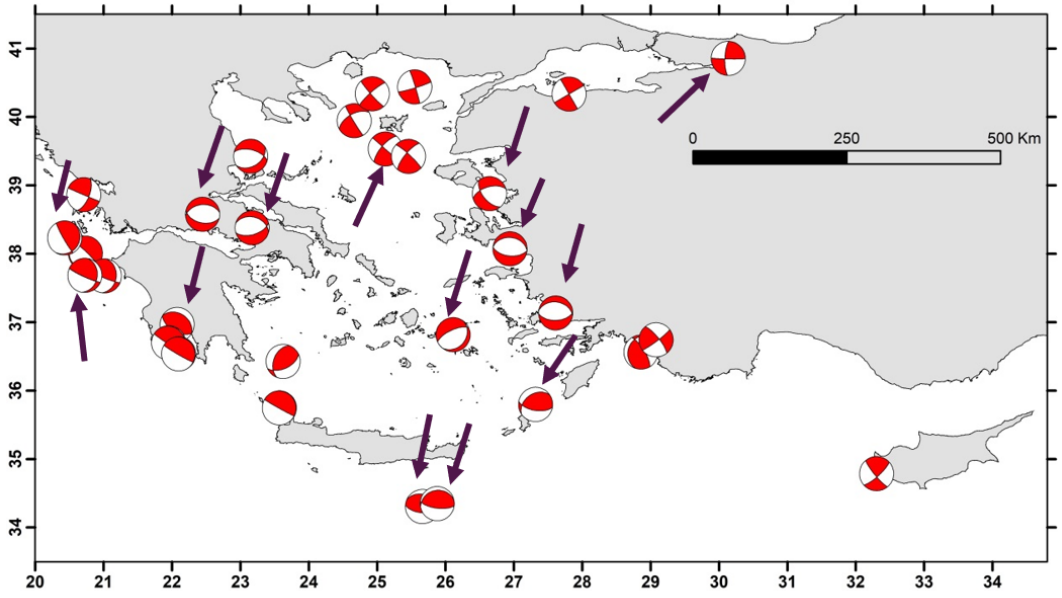


-Focal mechanisms available for 35 out 66 earthquakes.

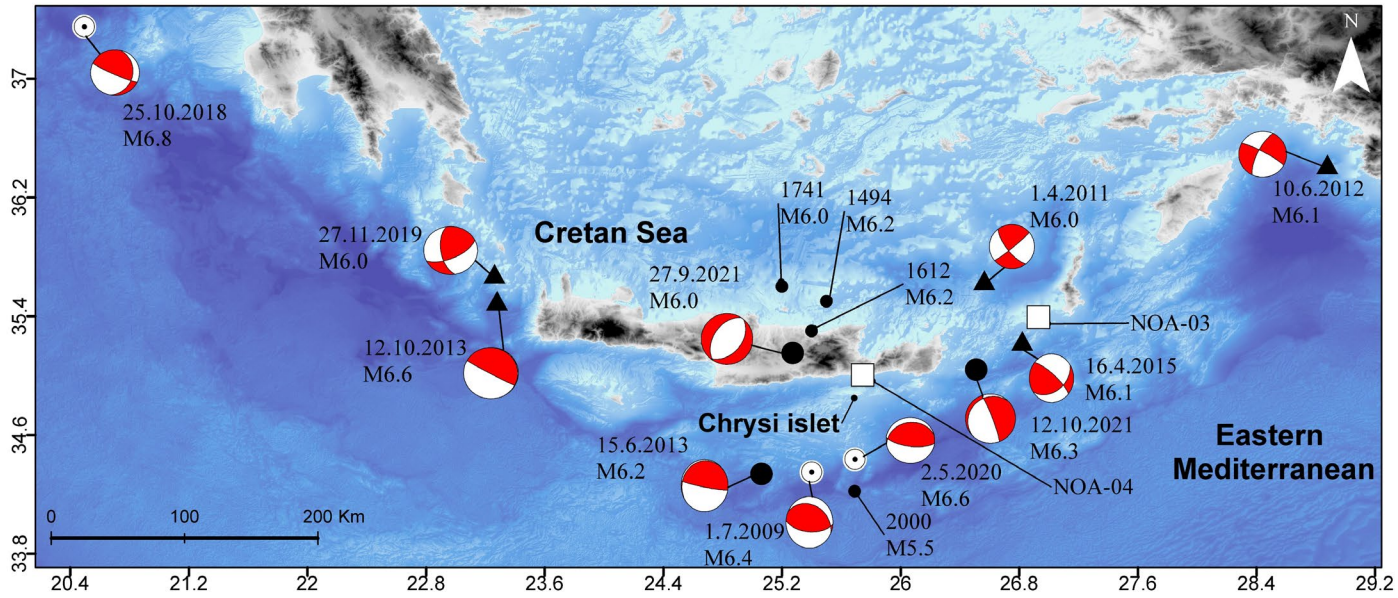
- 18 out of 35 are tsunamigenic earthquakes

- Most tsunamigenic EQs have dip-slip mechanism with ratio **14:18=0.78**.

- In the Marmara Sea and North Aegean Sea strike-slip prevails but only small tsunamis have been produced there.



Tsunamigenic earthquakes in HSZ 2009-2024

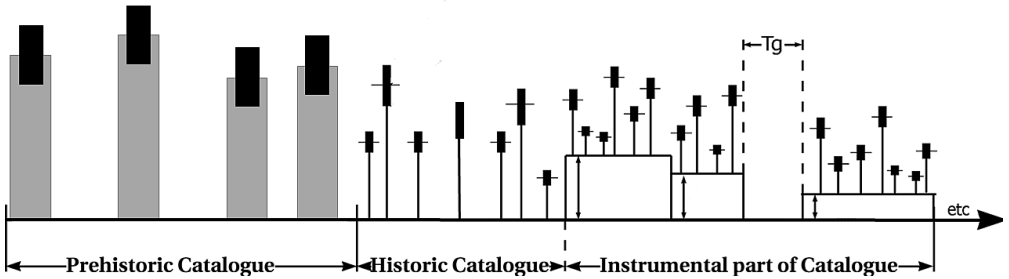


Triantafyllou et al. 2024

We examined 11 earthquakes of Mw ≥ 6.0 which occurred from 2009 to 2024. We found that three tsunamigenic earthquakes occurred (2009, 2018, 2020) with the following features:

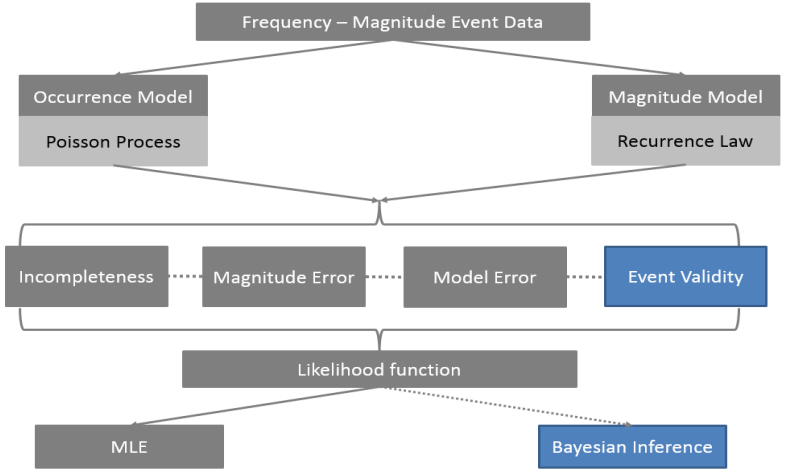
- Mw≥6.4,
- shallow depth (h<20 km),
- moderate-to-high dip-angle and thrust faulting or oblique slip with significant thrust component

Data-driven probabilistic tsunami risk assessment in the Mediterranean



-This method utilizes incomplete and complete catalog segments with different threshold tsunami intensities.

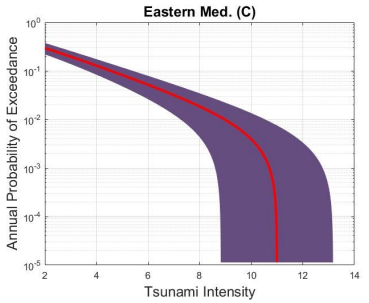
-The outputs include estimates of the probabilities of exceedance and return periods of given tsunami intensity levels.

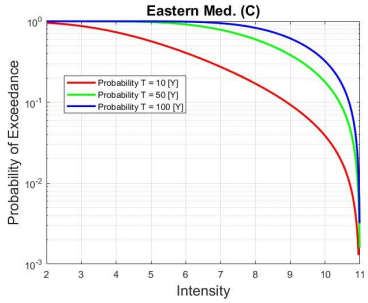


Smit et al., 2019

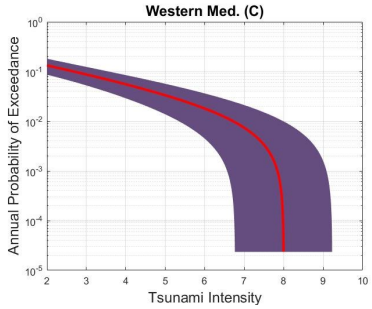
Probabilities of exceedance

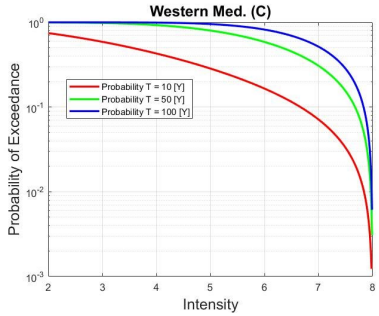
Eastern Mediterranean



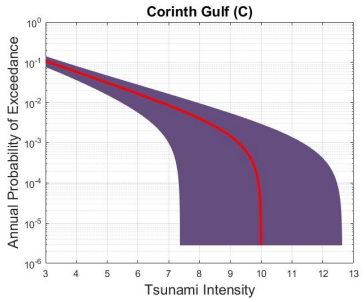


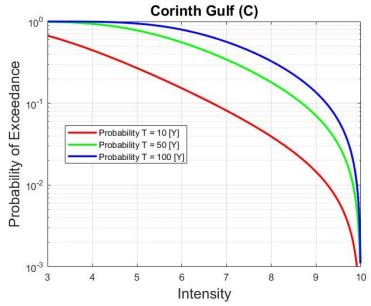
Western Mediterranean





Corinth Gulf





For intensity K≥7 (damaging tsunamis)

T=50 yrs
P=0.78
T=100 yrs
P=0.94

T=50 yrs
P=0.31
T=100 yrs
P=0.52

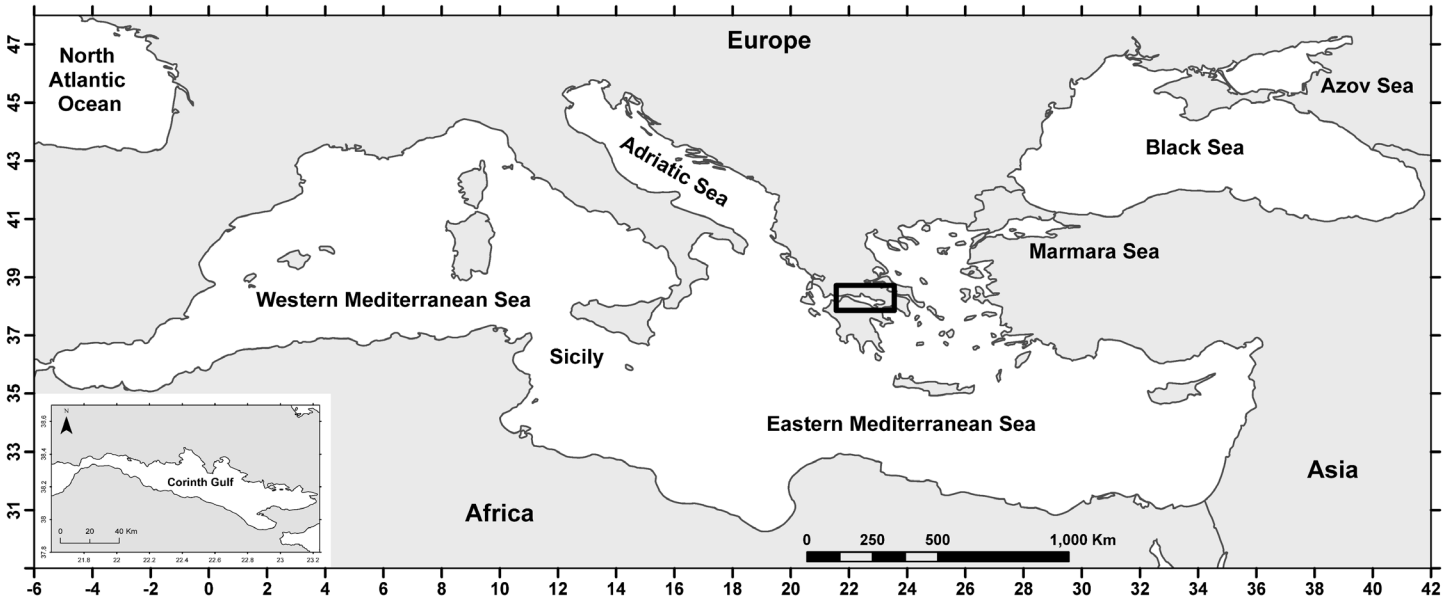
T=50 yrs
P=0.34
T=100 yrs
P=0.56

Lower P in the other basins

Triantafyllou et al. 2023

Results

- In the entire Mediterranean for K≥7 (damaging tsunami) repeat time is 22 yrs.
- Among the various Mediterranean basins the highest tsunami risk level was found in the Eastern Mediterranean.
- Significantly lower risk in the Western Mediterranean.
- The risk in the Corinth Gulf (Central Greece) is comparable to that of Western Mediterranean.
- In Marmara Sea the tsunami risk is low
- The lowest risk in Black Sea



Concluding remarks

- There is a clear increase of the tsunamigenic ratio with the increase of the earthquake magnitude. For $M_w \geq 7.5$ all EQs produce tsunamis.
- Tsunamis are produced by EQs with focal depth $h \leq 20$ km.
- Tsunamis are mainly produced by dip-slip mechanisms but in the Marmara Sea and North Aegean Sea strike-slip mechanisms cause small tsunamis.