TSUMAPS NEAM
Probabilistic TSUnami Hazard MAPS for the NEAM Region

- Agithar Kick-Off Meeting

AGITHAR

Mediterranean Conference Center

October 7-9, 2019, Valletta, Malta

- Roberto Basili and the TSUMAPS-NEAM Team

The NEAM Tsunami Hazard Model 2018 (NEAMTHM18)

Co-funded by the
European-Union Civil Protection Mechanism

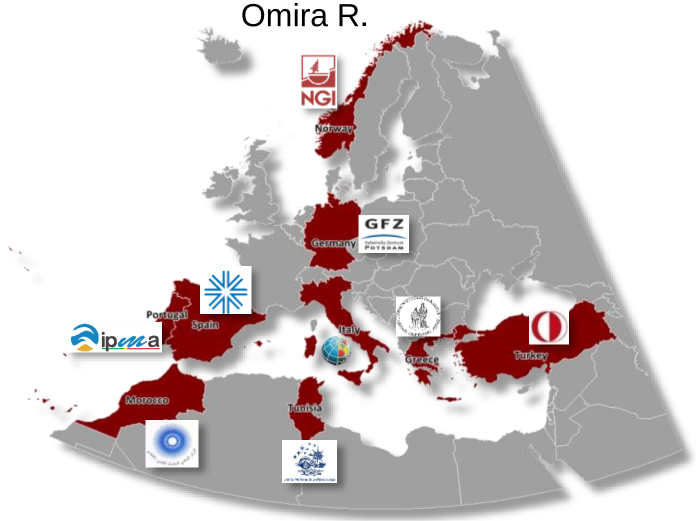
Agreement Number:
ECHO/SUB/2015/718568/PREV26

TSUMAPS-NEAM project objectives:

- produce the first region-wide long-term homogenous time-independent **PTHA** from **earthquake sources** for the **NEAM** coastlines;
- trigger a common tsunami risk management strategy in the region.

INGV	**NGI**	**IPMA**	**GFZ**	**METU**	**UB**	**NOA**	**CNRST**	**INM**
Italy	Norway	Portugal	Germany	Turkey	Spain	Greece	Morocco	Tunisia
Basili R. Lorito S. Selva J. Brizuela B. Iqbal S. Maesano F.E. Murphy S. Perfetti P. Romano F. Scala A. Taroni M. Thio H.K. Tiberti M.M. Tonini R. Volpe M. Herrero A.	Harbitz C.B. Løvholt F. Glimsdal S.	Baptista M.A. Carrilho F. Matias L. Omira R.	Babeyko A. Hoechner A.	Yalciner A. Pekcan O. Gurbuz M.	Canals M. Lastras G.	Papadopoulos G. Agalos A. Triantafyllou, I.	Benchekroun S.	Ben Abdallah S. Agrebi Jaouadi H. Attafi K. Bouallegue A. Hamdi H. Oueslati F.

Duration: ***21 months***
(01/01/2016 - 30/09/2017)



End Users and Advisers

PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

EUROPEAN COMMISSION
JOINT RESEARCH CENTRE
Institute for the Protection and Security of the Citizen
The Director

EPOS

USGS science for a changing world

UNESCO

SRB-RAS

EWS-CARIBE

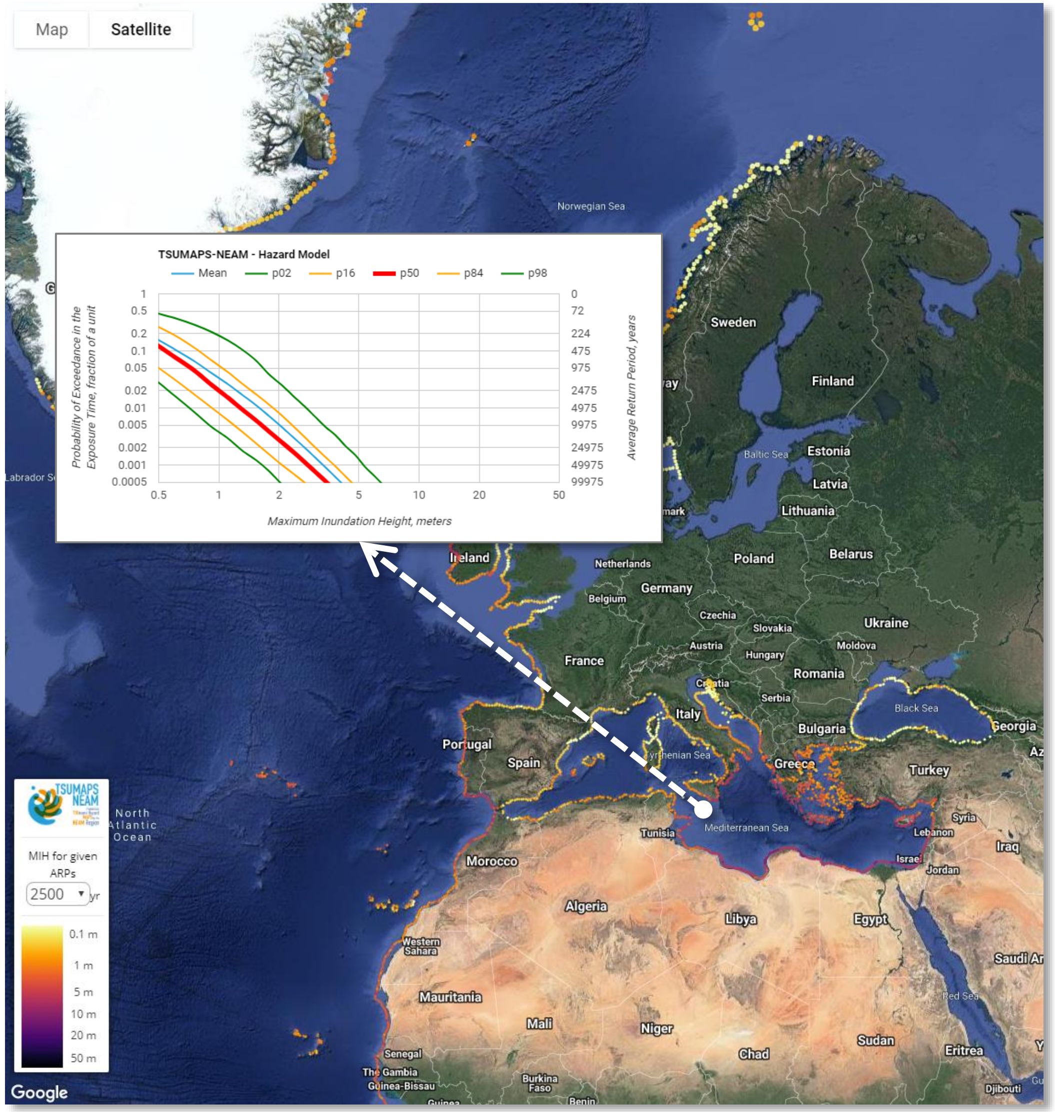
BOĞAZİÇİ UNIVERSITY
KANDİLLİ OBSERVATORY and EARTHQUAKE RESEARCH INSTITUTE

National Institute of Oceanography & Fisheries

HPC support by

HySEA

CINECA



Basili, and 39 coauthors (2018) http://doi.org/10.13127/tsunami/neamthm18.

http://www.tsumaps-neam.eu/neamthm18/

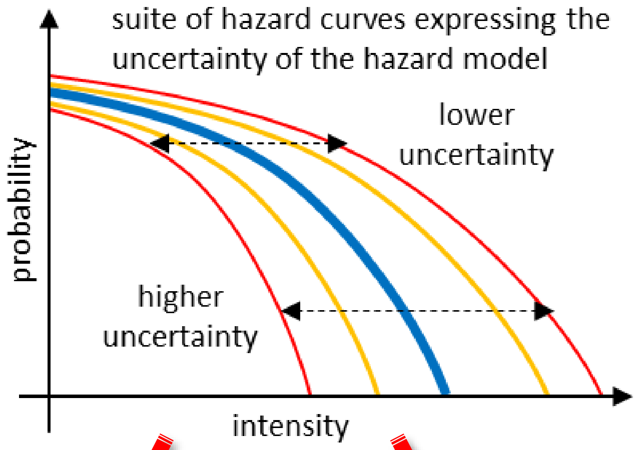
NEAMTHM18 Portfolio

- **Hazard curves** calculated at **2,343 POIs** (North-Eastern Atlantic: 1,076; Mediterranean Sea: 1,130; Black Sea: 137) at an average spacing of **~20 km**.
- For each curve, values for **mean, 2nd, 16th, 50th, 84th, 98th** percentiles.
- **Probability maps** for **MIH 1, 2, 5, 10, 20** meters;
- **Hazard maps** for **ARP 500, 1000, 2500, 5000, 10000** years
- Map displays for **mean, 16th, 84th** percentiles.
- **Interactive** Hazard Map and Curve **Tool**
- Comprehensive **Documentation** with two review reports (352 pp.)

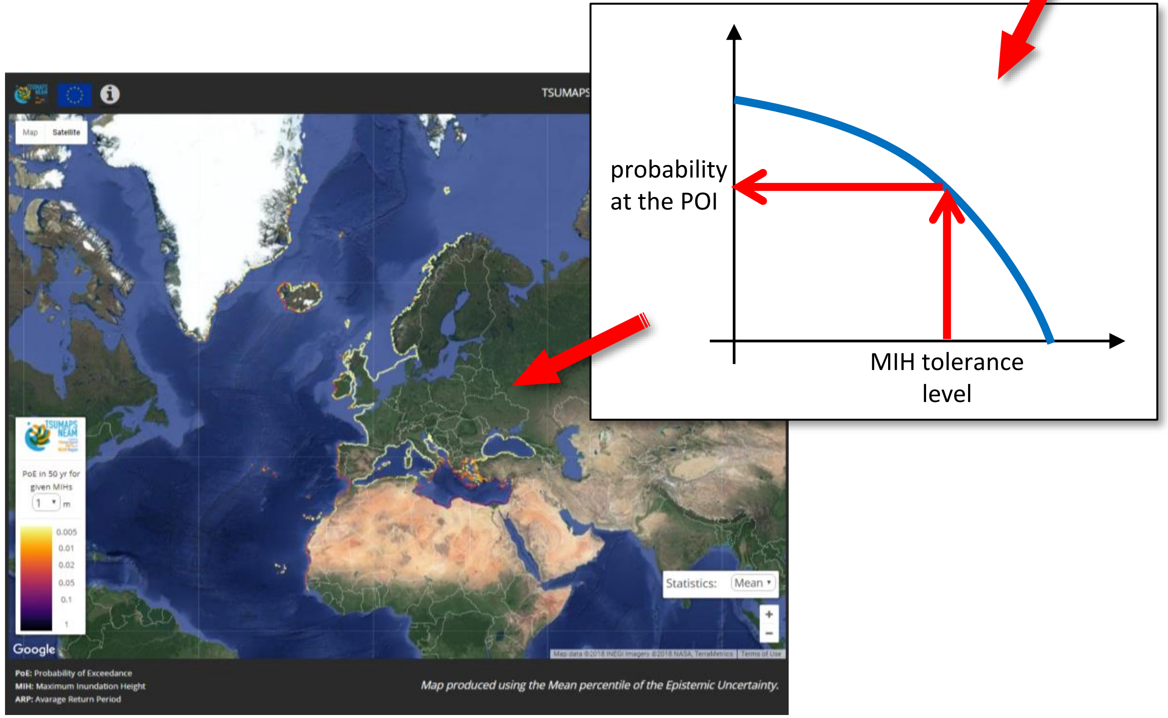
By-products

- *Database of pre-calculated tsunami scenarios for over 120,000 elementary sources for c. 30 Tb, covering an area of c. 6x10^6 km^2*
- *Hazard calculation platform*
- *Amplification Factors*

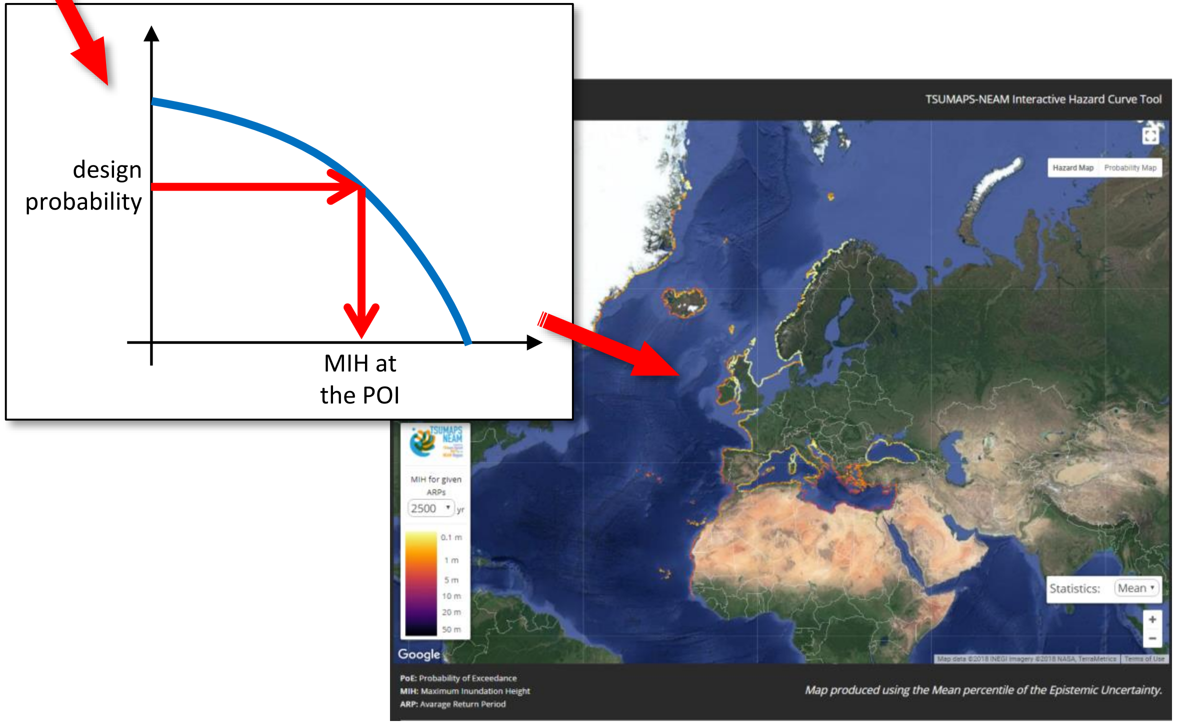
Results: Probability and Hazard Maps



PROBABILITY MAPS



HAZARD MAPS



Strengths & Opportunities

- Relies on robust data and methods from previous EU projects
- Community-based effort
- Ensemble uncertainty modeling
- Multi-expert integration process for managing epistemic uncertainty
- Independent external review

Ready to be used as…

- …reference in National PTHA mapping
- …support for the definition of evacuation zones for Tsunami Warning Systems
- …developing guidelines and standards for tsunami hazard and risk at global scale

Weaknesses & Threats

- Regional scale not suitable for local assessment, NEAMTHM18 is not a replacement for local/national assessments
- Seismic source discretization (position, parameters) is very coarse
- POIs discretization is coarse (c. 20 km)
- Amplification factors as proxy for inundation
- Use of expected values from empirical relationships
- Inhomogeneous catalogs of earthquakes, focal mechanisms, faults, subduction zones
- Earthquake rates only from catalogs for crustal sources; geodetic/geologic rates for few selected faults only
- *… and once again, <u>only earthquake sources were considered!</u>*

Hazard assessment: workflow & basic principles

- Hazard assessment: STEPS & Levels workflow -

STEP 1 – **Probabilistic earthquake model**

Levels:
- Regionalization and seismic datasets
- Magnitude-Frequency Distribution (MFD)
- Earthquake rupture parameters for different seismicity modeling types for each magnitude of the MFD

STEP 2 – **Tsunami generation & modeling in deep water**

Levels:
- Crustal model, topo-bathymetric datasets, and DEMs, POIs
- Coseismic displacement
- Tsunami generation model
- Tsunami propagation model in deep water

STEP 3 – **Shoaling and inundation**

Levels:
- Topo-bathymetric datasets and DEMs, bathymetric transects, amplification factors
- Amplification and inundation model
- Uncertainty modeling for tsunami hazard metrics

STEP 4 – **Hazard aggregation & uncertainty quantification**

Levels:
- Elicitation of experts and tsunami DB
- Combination of STEPS from 1-3
- Quantification of uncertainty
- Comparison/test with tsunami records & disaggregation

- Adopt data and methods from recent European Projects (ASTARTE, SHARE, STREST)
- Treatment of all seismic sources without pre-selections
  - → Probabilistic approach
  - → Earthquakes possible everywhere
- Use of all the available information
  - → Well-known sources received special treatment
  - → Controlled simplifications according to scale and computational feasibility
- Quantification of the epistemic uncertainty
  - → Variability within scientifically acceptable models
  - → Community distribution and ensemble model
- Transparent treatment of subjectivity of choices
  - → Multiple-Expert Management Protocol

Hazard assessment: workflow & basic principles

- Hazard assessment: STEPS & Levels workflow -

STEP 1 – Probabilistic earthquake model
→ Levels: Regionalization and seismic datasets | Magnitude-Frequency Distribution (MFD) | Earthquake rupture parameters for different seismicity modeling types for each magnitude of the MFD

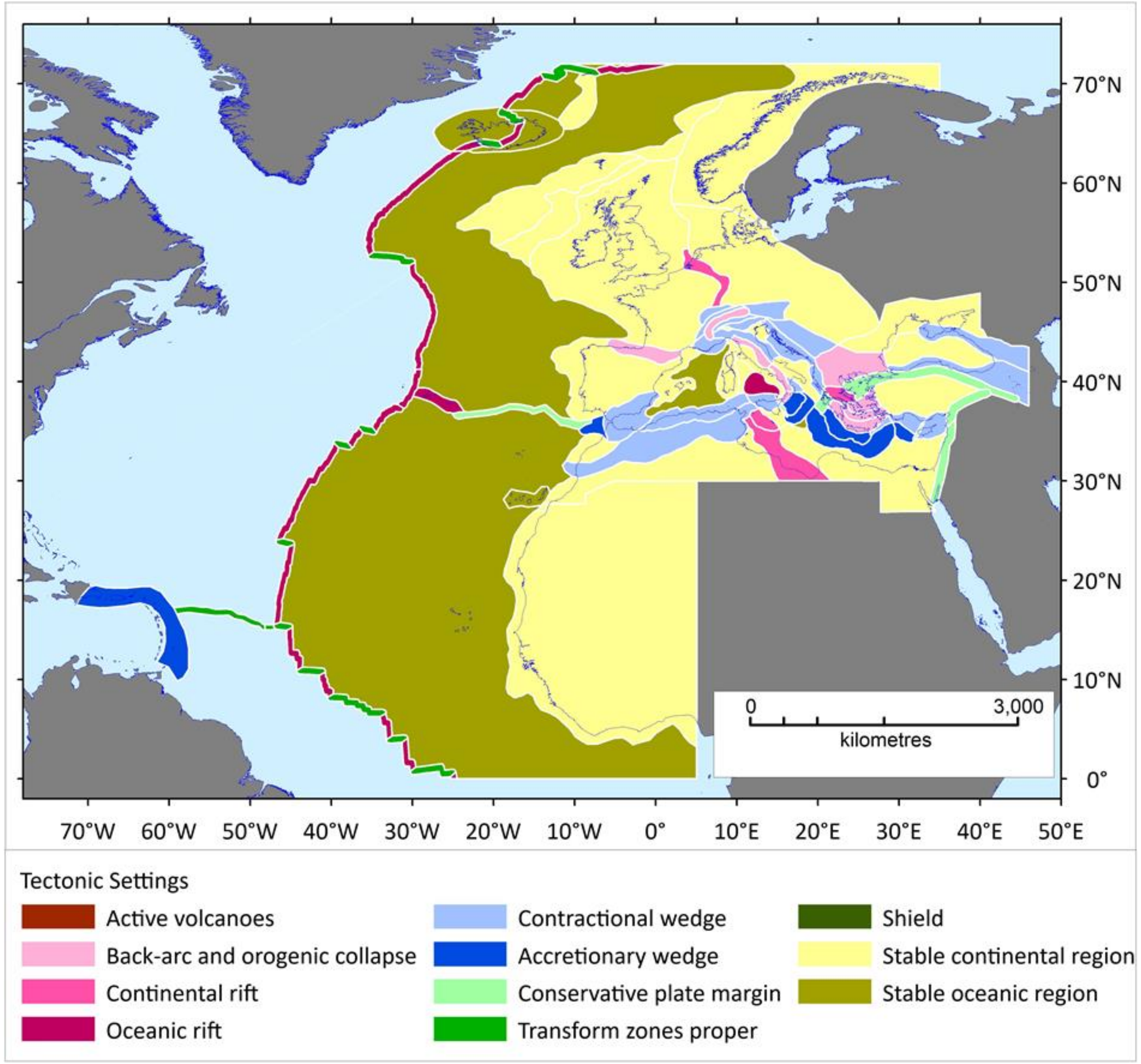
STEP 2 – Tsunami generation & modeling
→ Levels: Crustal model, topo-bathymetric datasets, and DEMs, POIs | Coseismic displacement | Tsunami generation | Tsunami propagation model

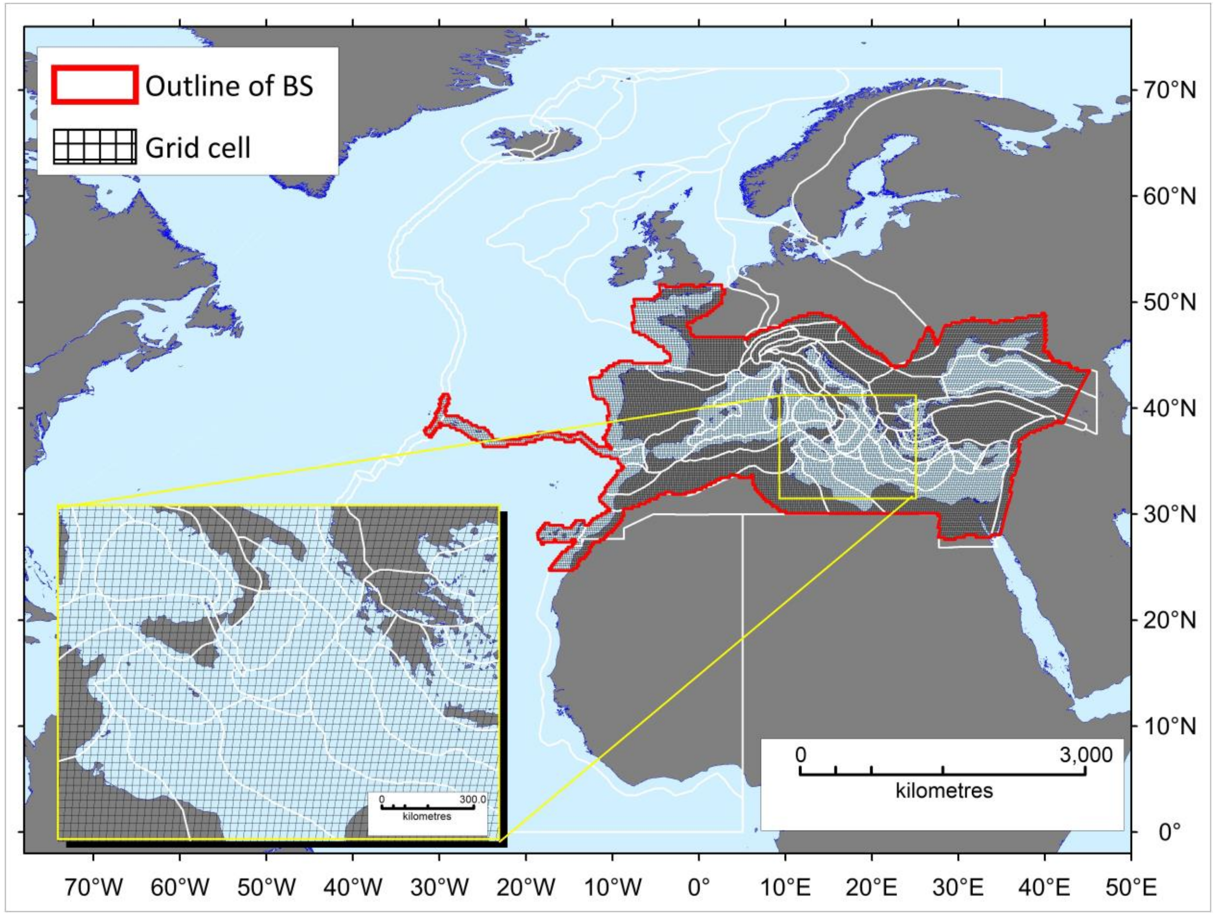
STEP 3 – Shoaling and inundation
→ Levels: Topo-bathymetric datasets and DEMs, bathymetric transects, amplification factors | Amplification and inundation model | Uncertainty modeling for tsunami hazard metrics

STEP 4 – Hazard aggregation & uncertainty quantification
→ Levels: Elicitation of experts and tsunami DB | Combination of STEPS from 1-3 | Quantification of uncertainty | Comparison/test with tsunami records & disaggregation

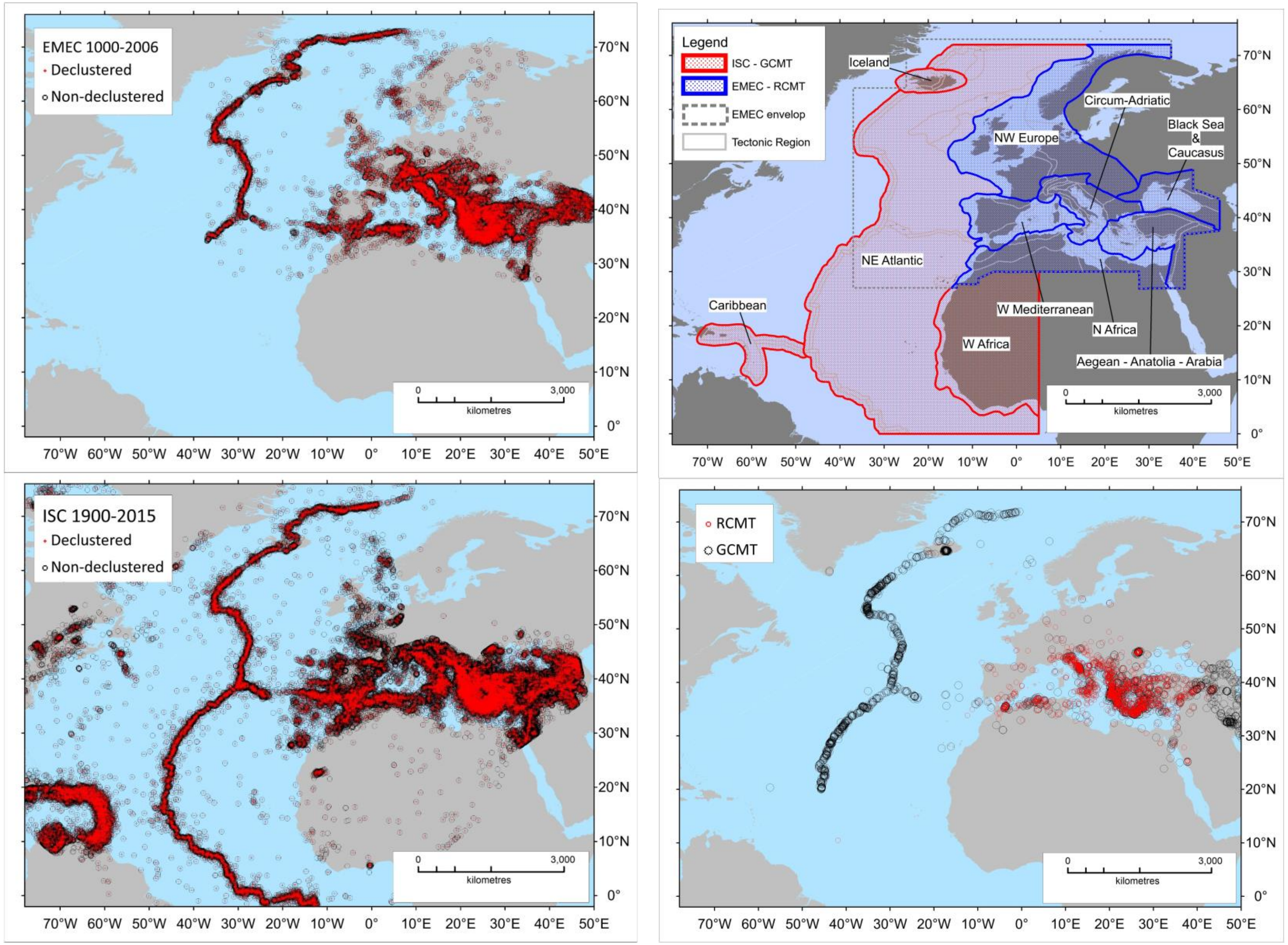
STEP 1 – Probabilistic earthquake model
→ Levels: Regionalization and seismic datasets | Magnitude-Frequency Distribution (MFD) | Earthquake rupture parameters for different seismicity modeling types for each magnitude of the MFD

- Adopt data and methods from recent European Projects (ASTARTE, SHARE, STREST)
- Treatment of all seismic sources without pre-selections
  - → Probabilistic approach
  - → Earthquakes possible everywhere
- Use of all the available information
  - → Well-known sources received special treatment
  - → ... scale and ...
- Quantification of the epistemic uncertainty
  - → Variability within scientifically acceptable models
  - → Community distribution and ensemble model
- Transparent treatment of subjectivity of choices
  - → Multiple-Expert Management Protocol





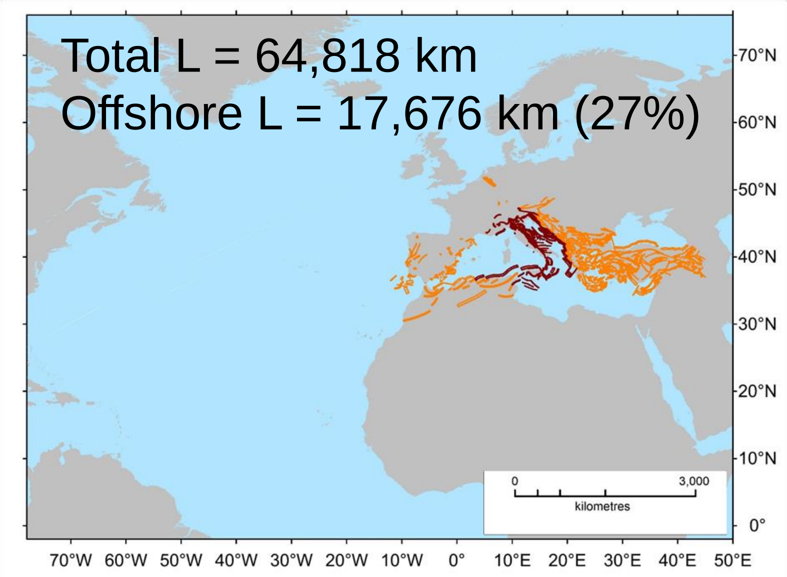
- 110 source zones
- 13,862 grid cells
- tens of millions seismic scenarios
- more than 2,000 POIs



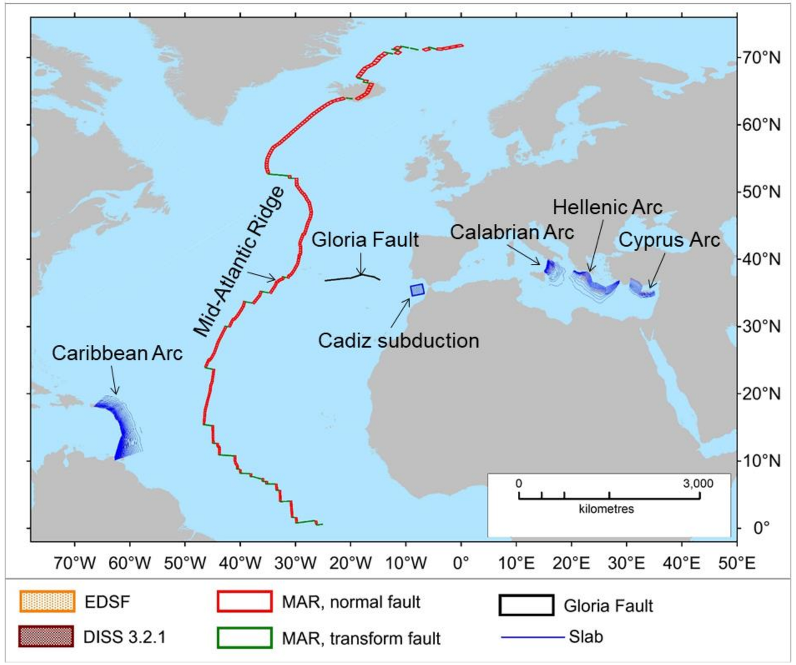
- SHEEC-EMEC time span 1000-2006 (Stucchi et al., 2012; Grünthal & Wahlström, 2012)
- ISC (ISC, 2016) time span 1900-2015
- GCMT (Dziewonski et al., 1981; Ekström et al., 2012)
- RCMT (Pondrelli & Salimbeni, 2015)

Seismic sources: input data

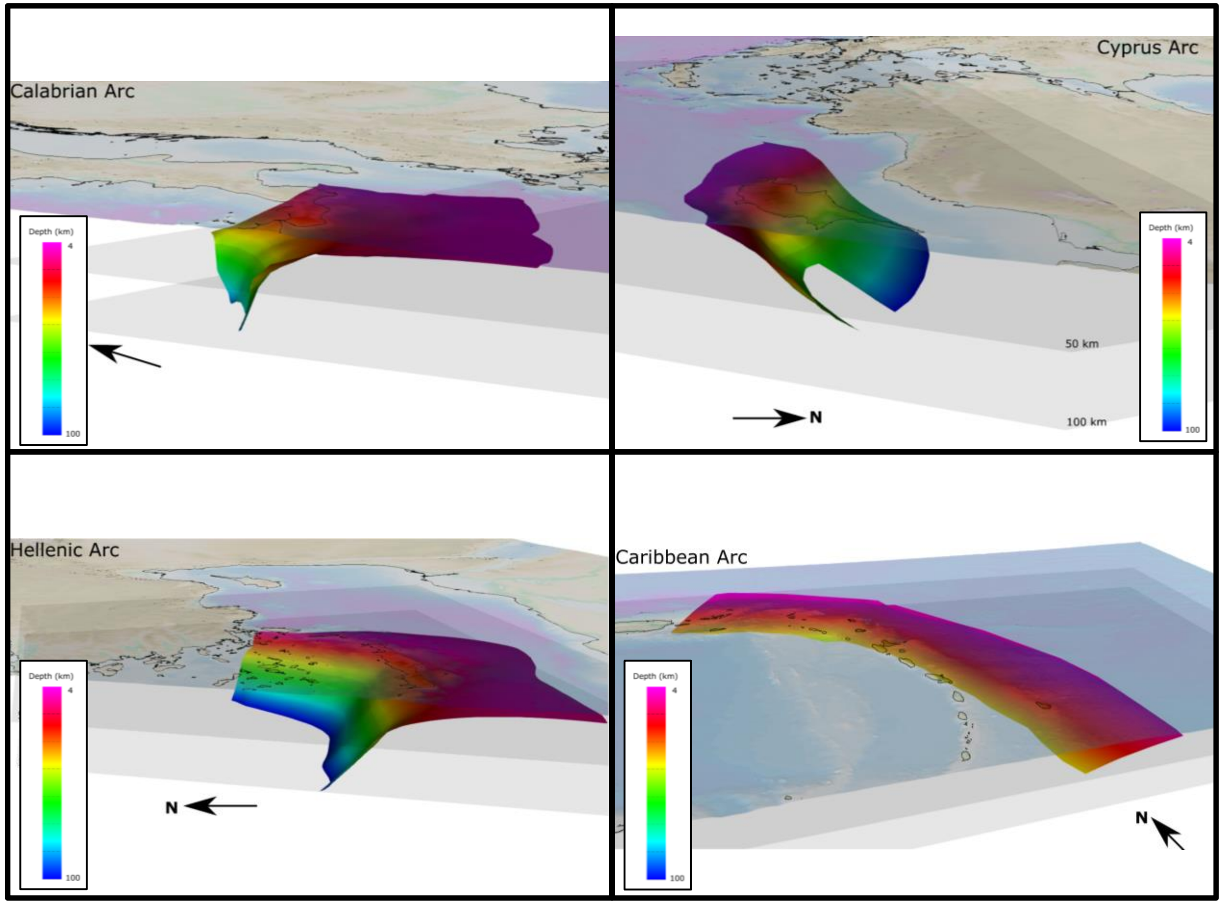
Crustal faults



Slabs and main plate boundaries

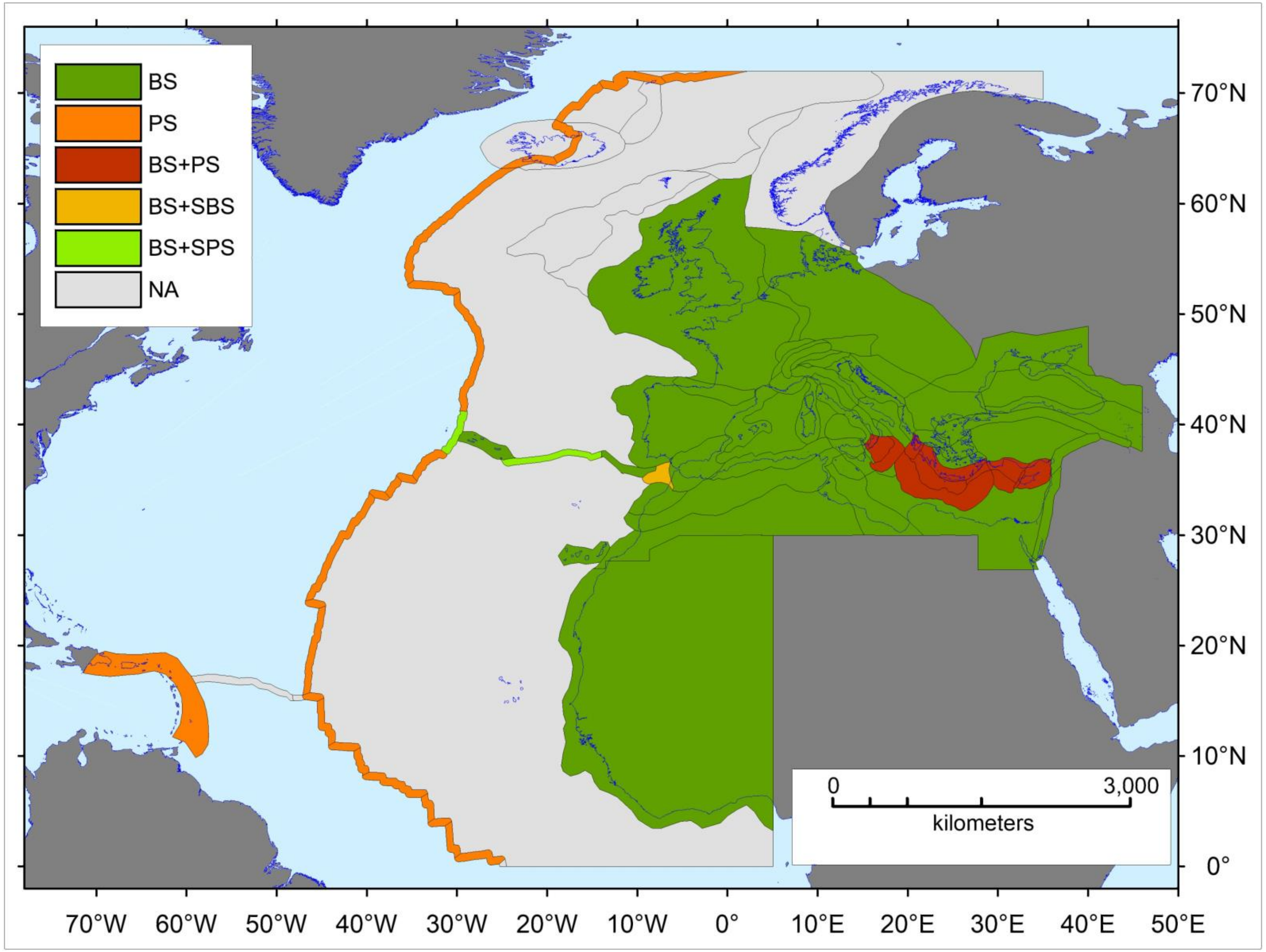


Slab complex 3D geometries



- EDSF (Basili et al., 2013)
- DISS 3.2.1 (DISS WG, 2018)

- PB2002 Bird (2003)
- SLAB 2.0 (Hayes et al., 2018)
- CAS (Maesano et al., 2017)

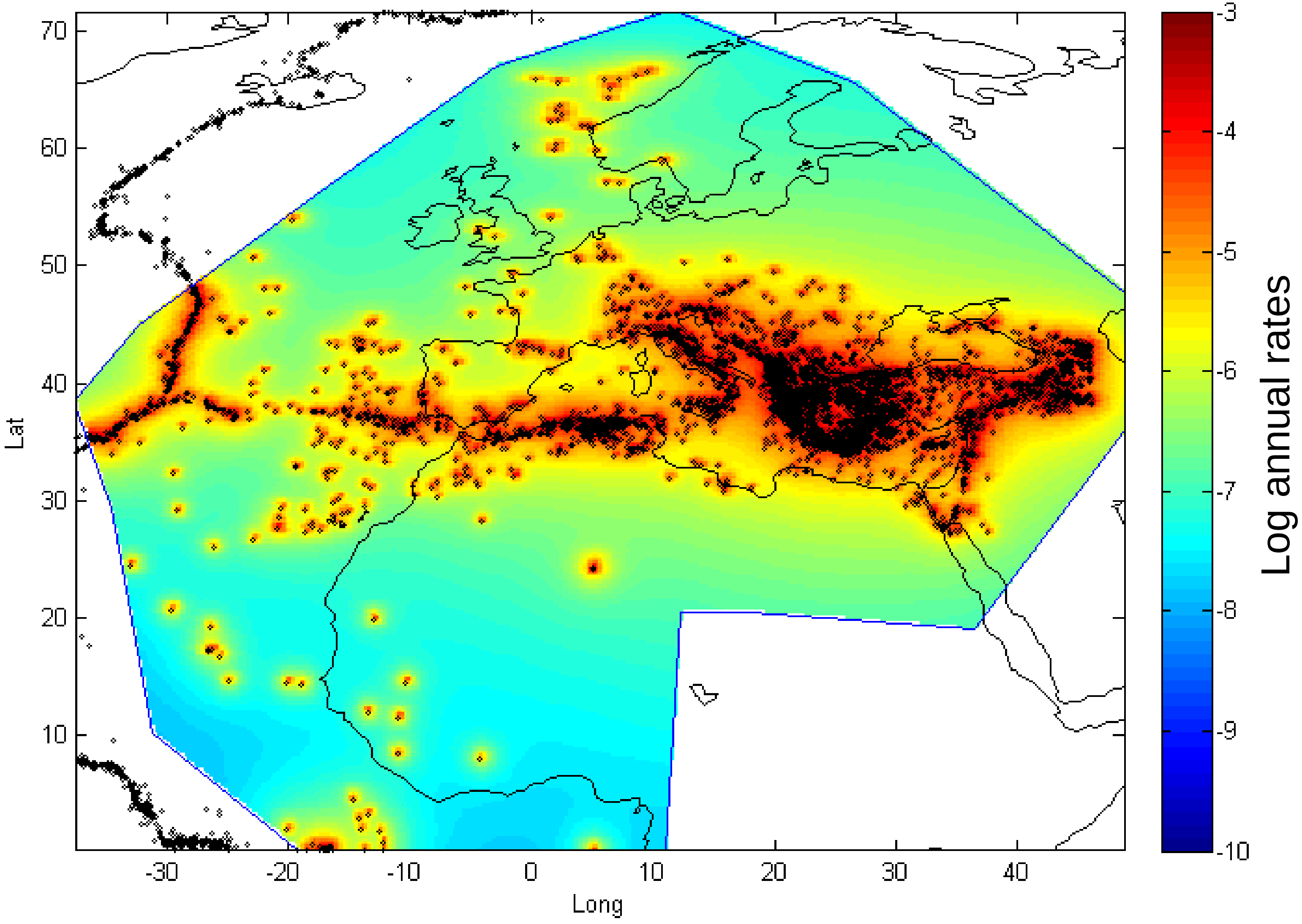


Background Seismicity (BS)
The BS seismicity modeling type is meant to capture all the seismicity for which there is a low level of knowledge, including the smaller earthquakes of interest and deals with faults characterized by the largest variability.

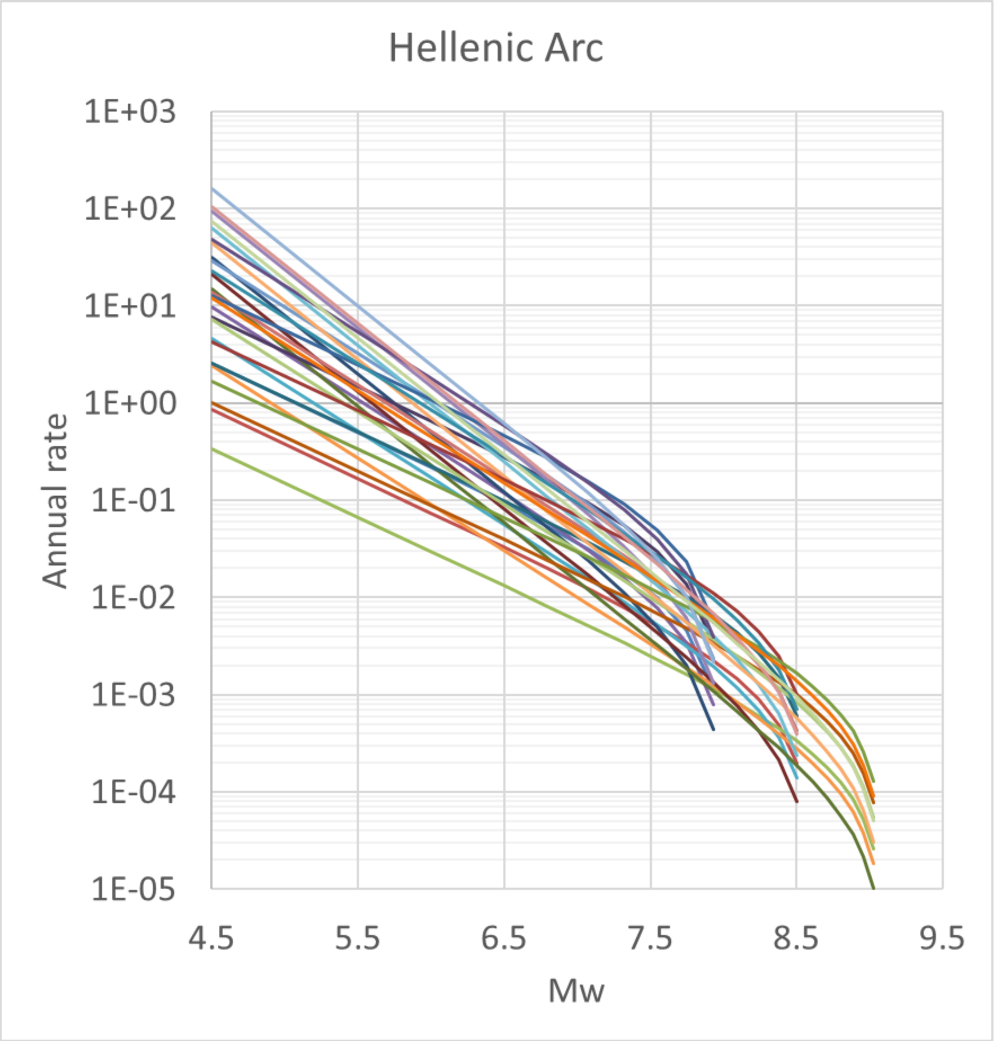
Predominant Seismicity (PS)
The PS seismicity modeling type is meant to capture the larger earthquakes generated by rather well-known major faults, e.g. plate boundaries and, particularly, subduction zones.

Seismic sources: earthquake rates

Smoothing method adopted from Hiemer et al. (2014)



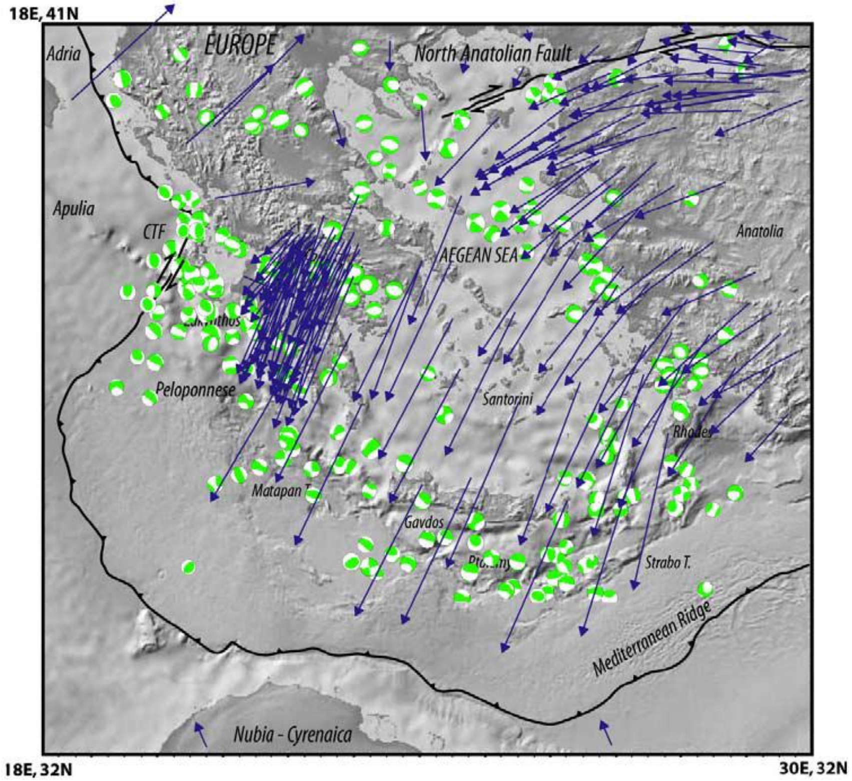
Seismic sources: earthquake rates alternative model for PS



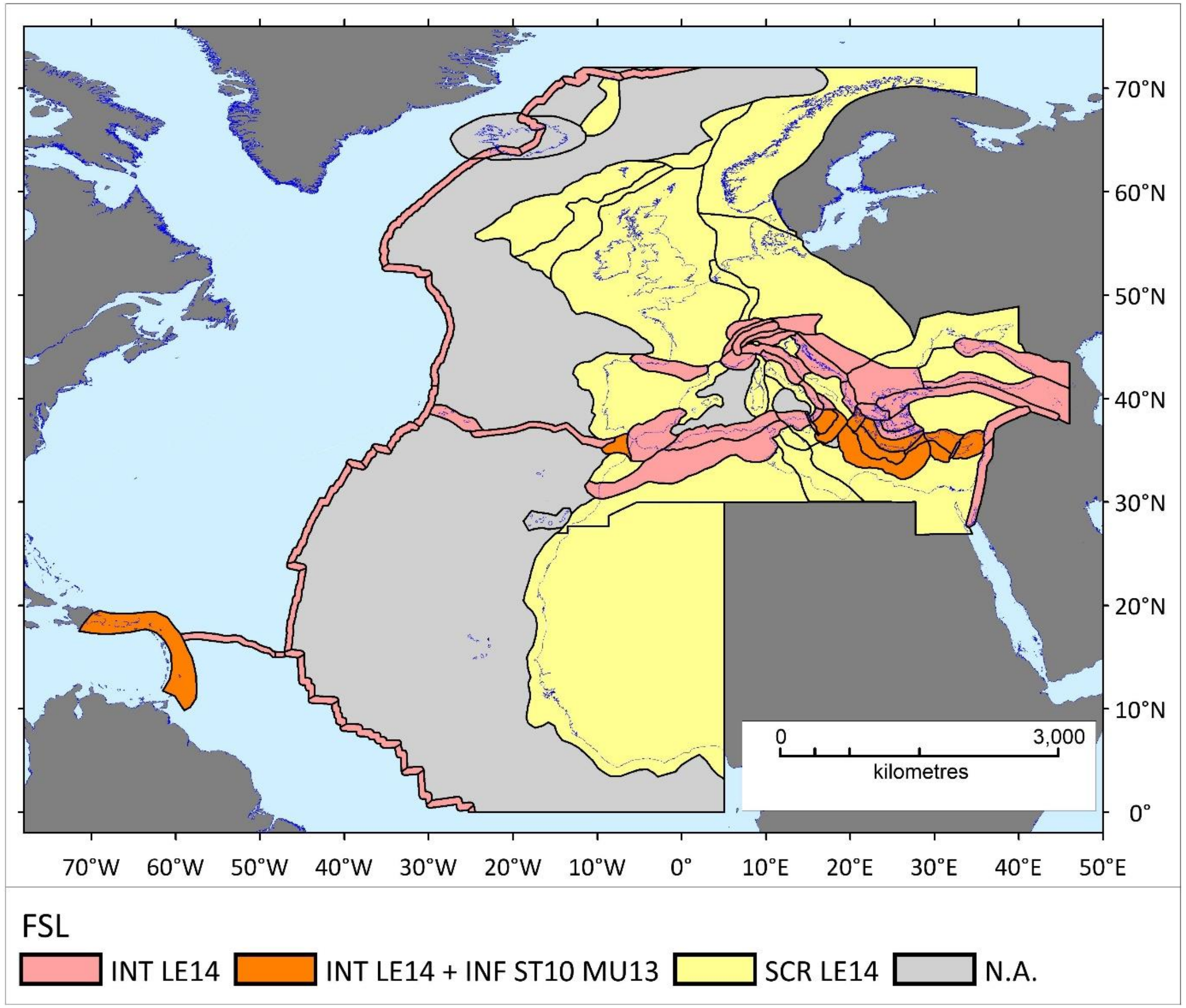
b = 0.70, 0.95, 1.20
c = 0.2, 0.6, 1.0
Mx = 8.0, 8.6, 9.1

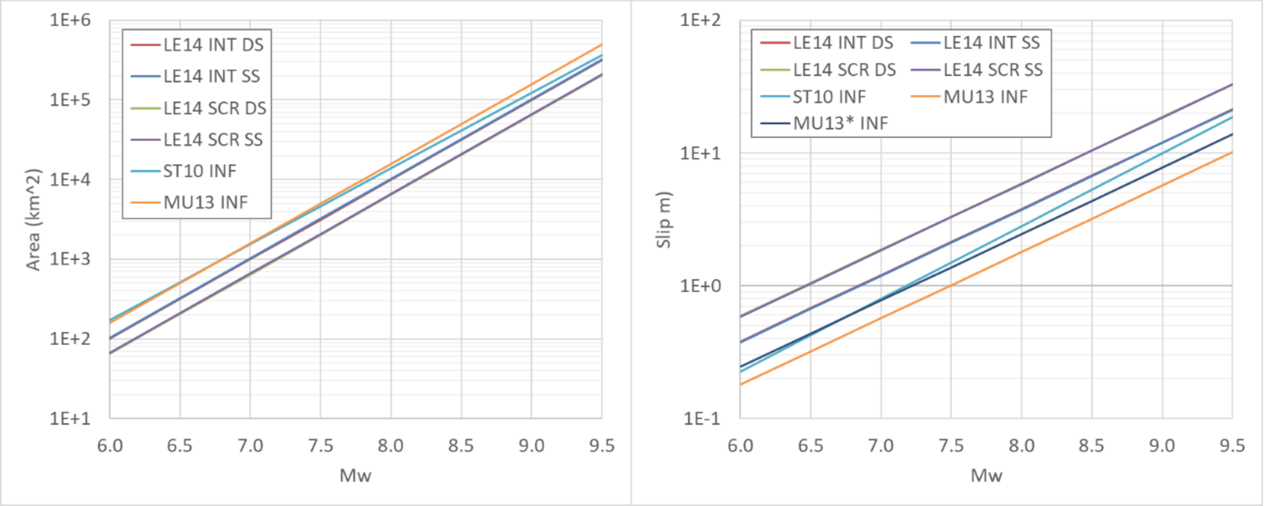
Data of convergence rates, b-value, coupling, and Mmax from Davies et al. (2018)

Truncated MFD model from Kagan (2002)



GPS velocities in the Hellenic Arc, figure from Ganas and Parsons (2009)





Map distribution of the fault scaling relations

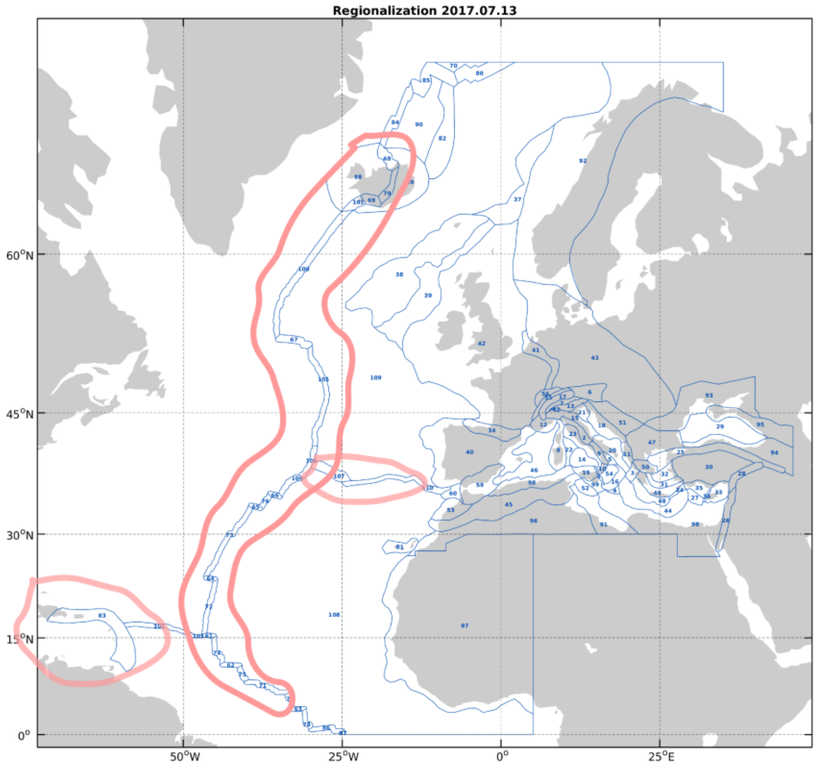
- LE14: Leonard (2014)
- ST10: Strasser et al. (2010)
- MU13: Murotani et al. (2013)

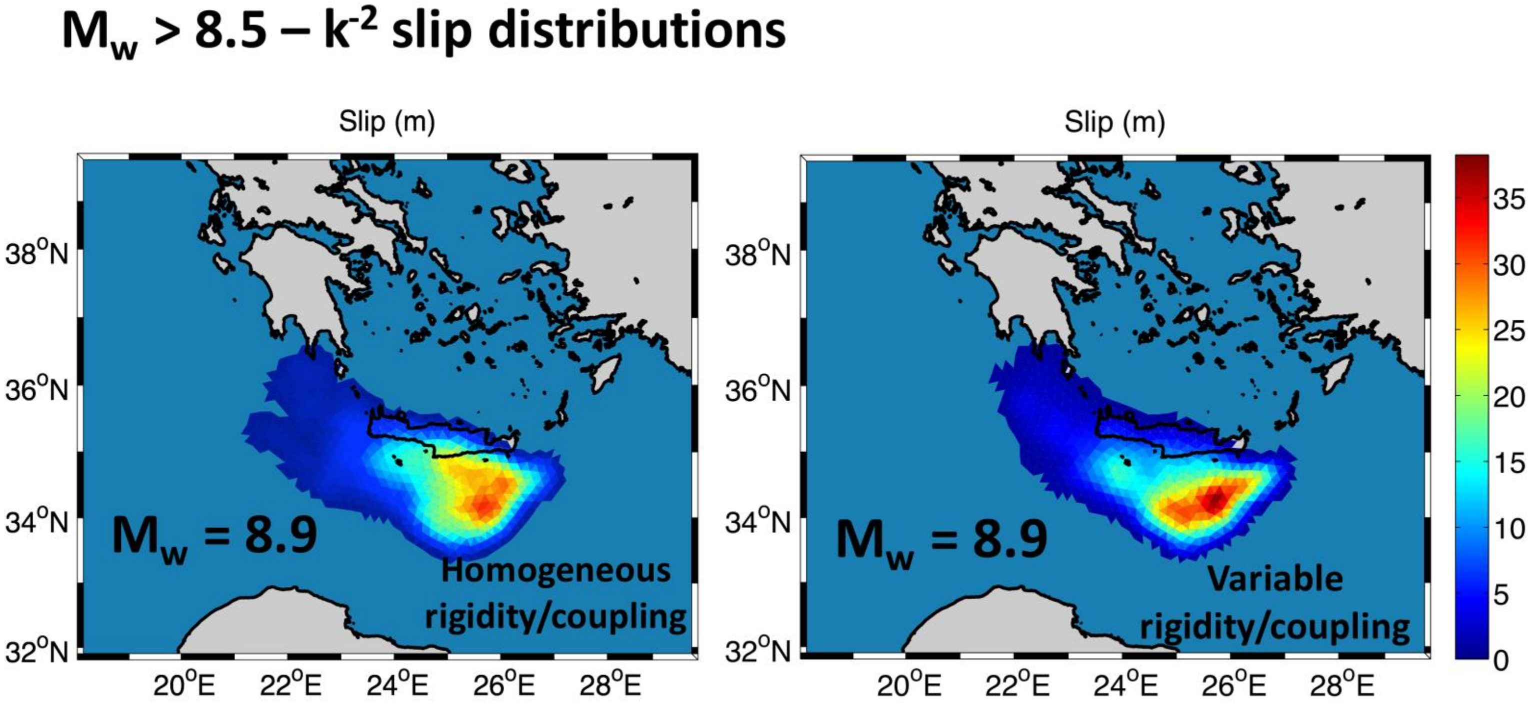
- INT = interplate
- SCR = stable continental region
- INF = slab interface

Faulting mechanisms of crustal faults are assigned based on moment tensors and fault data. Only reverse slip faulting applies to subduction interface.

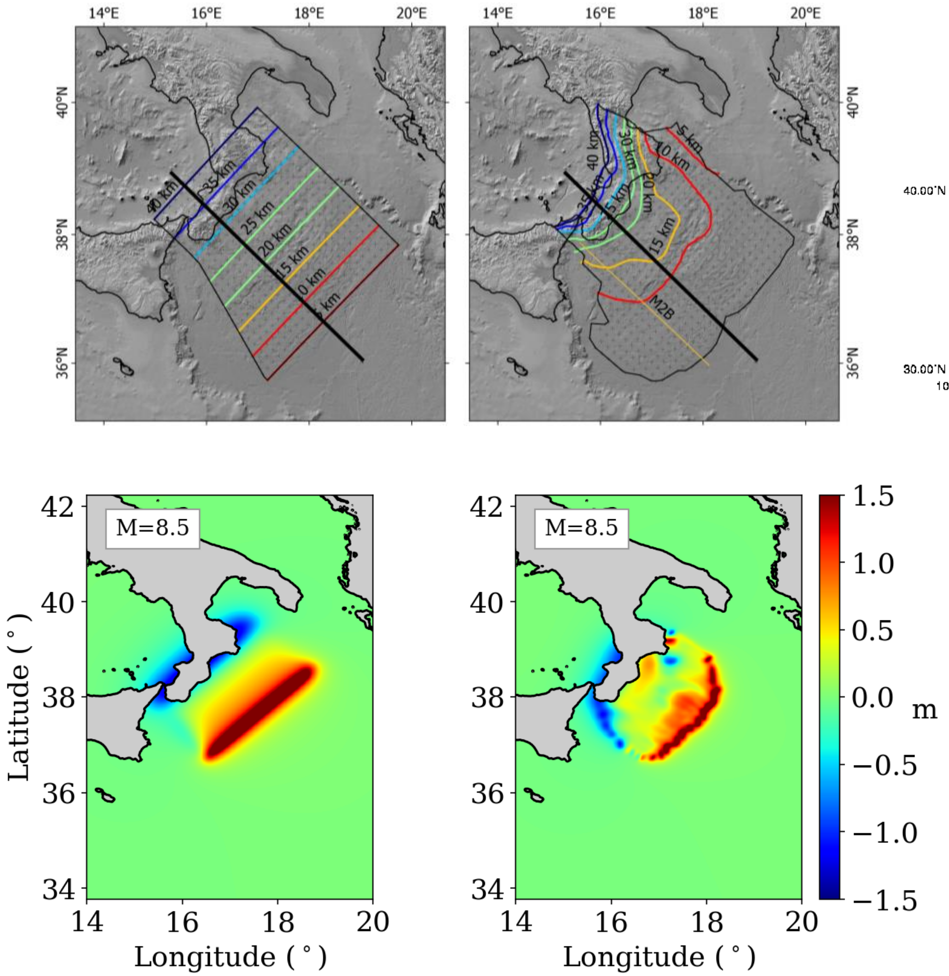
BS + PS far-field sources:
use “classical” propagation Green’s functions from unit slip on planar fault segments

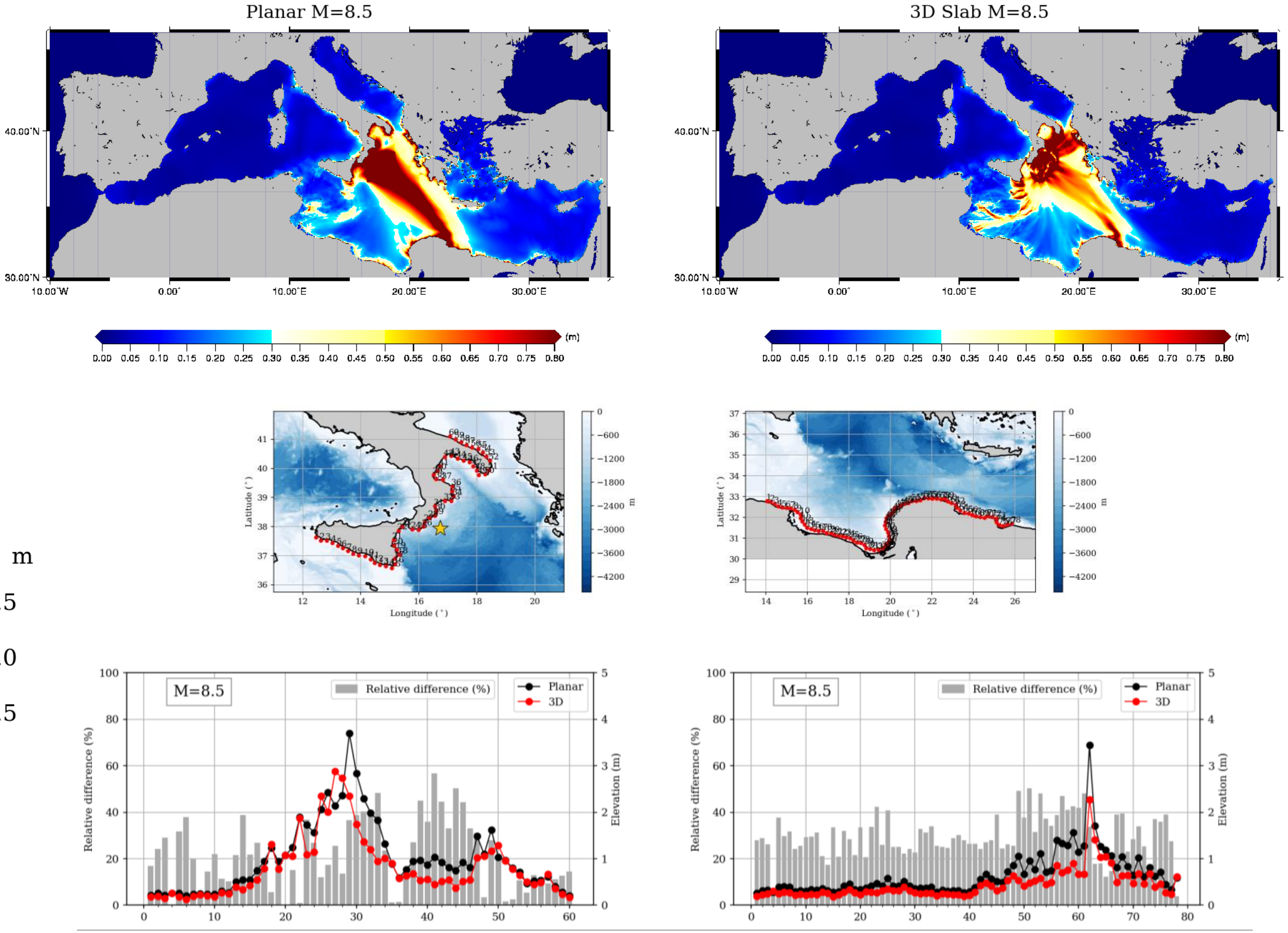
PS near-field sources:
3D Geometry
Stochastic Slip
Shallow slip
Depth-dependent rigidity





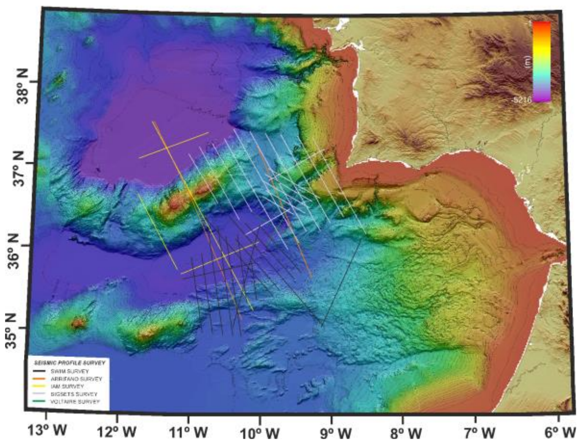
Seismic sources: rupture models – planar vs 3D geometry

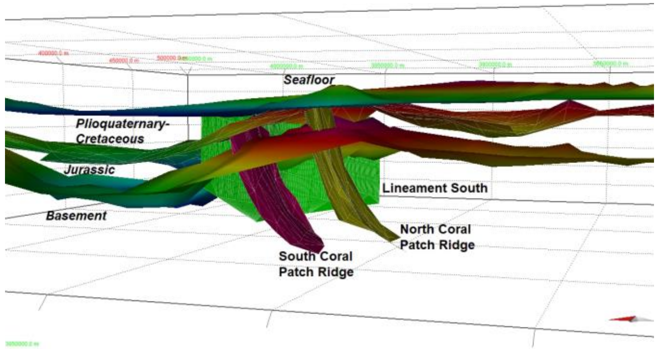




Tonini et al. (*in prep.*)

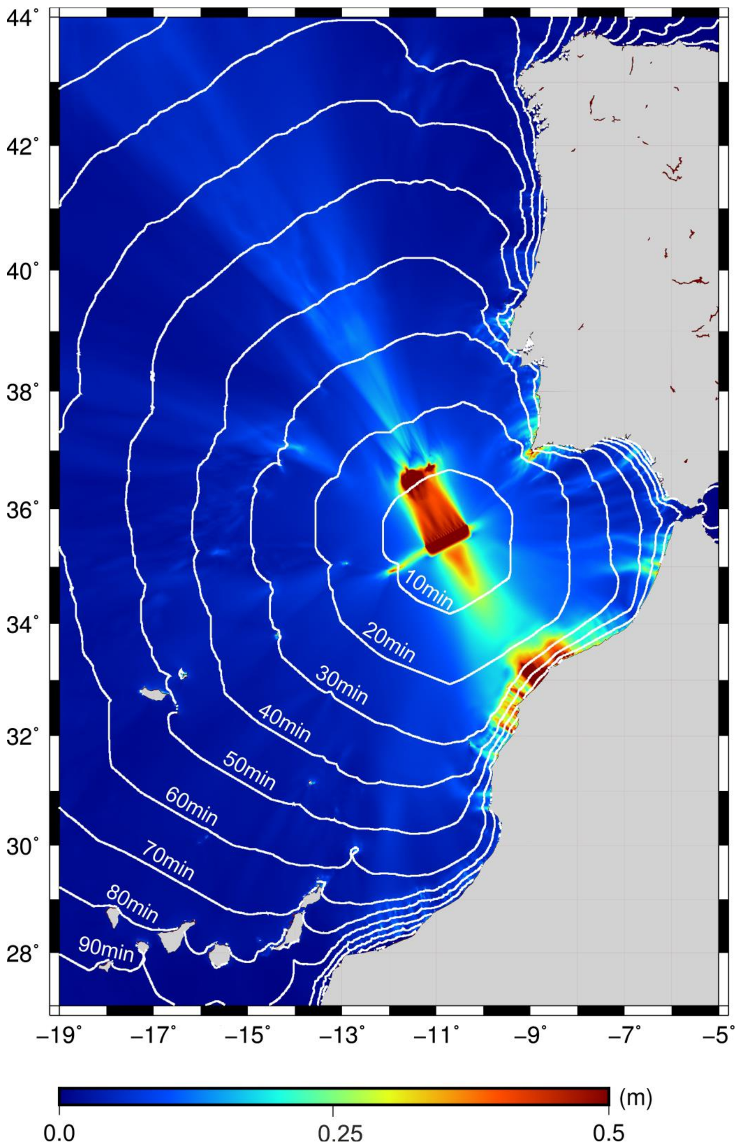
Serra et al. (*in prep.*)

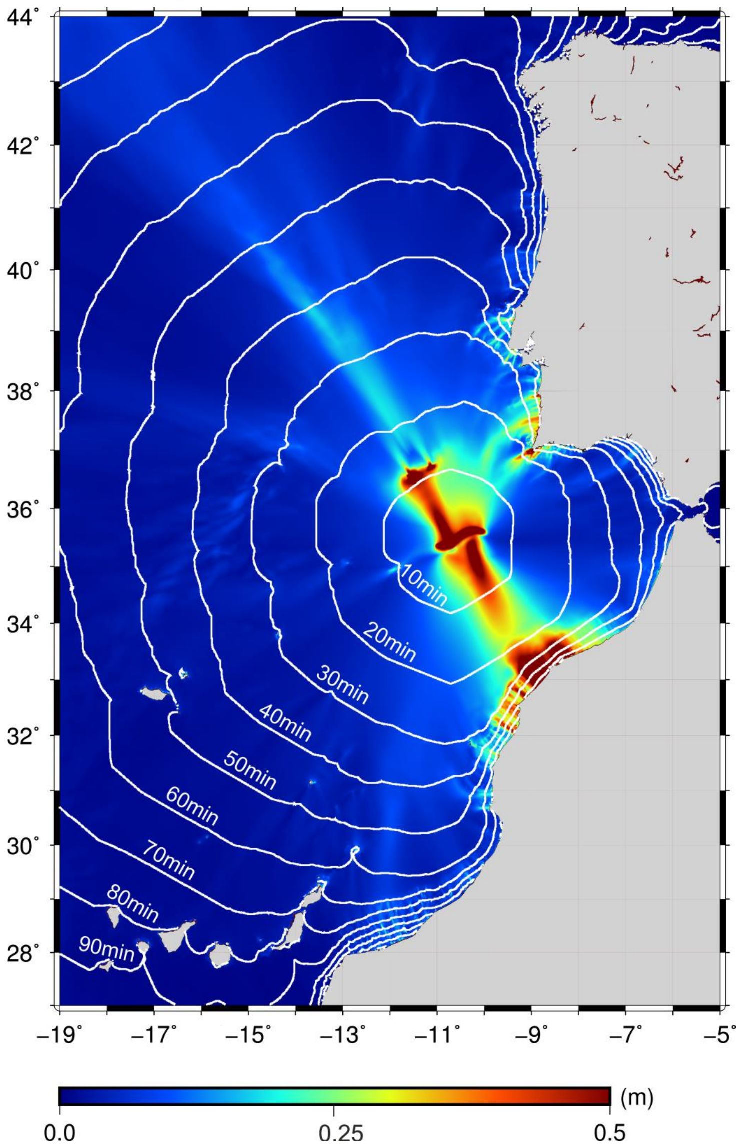




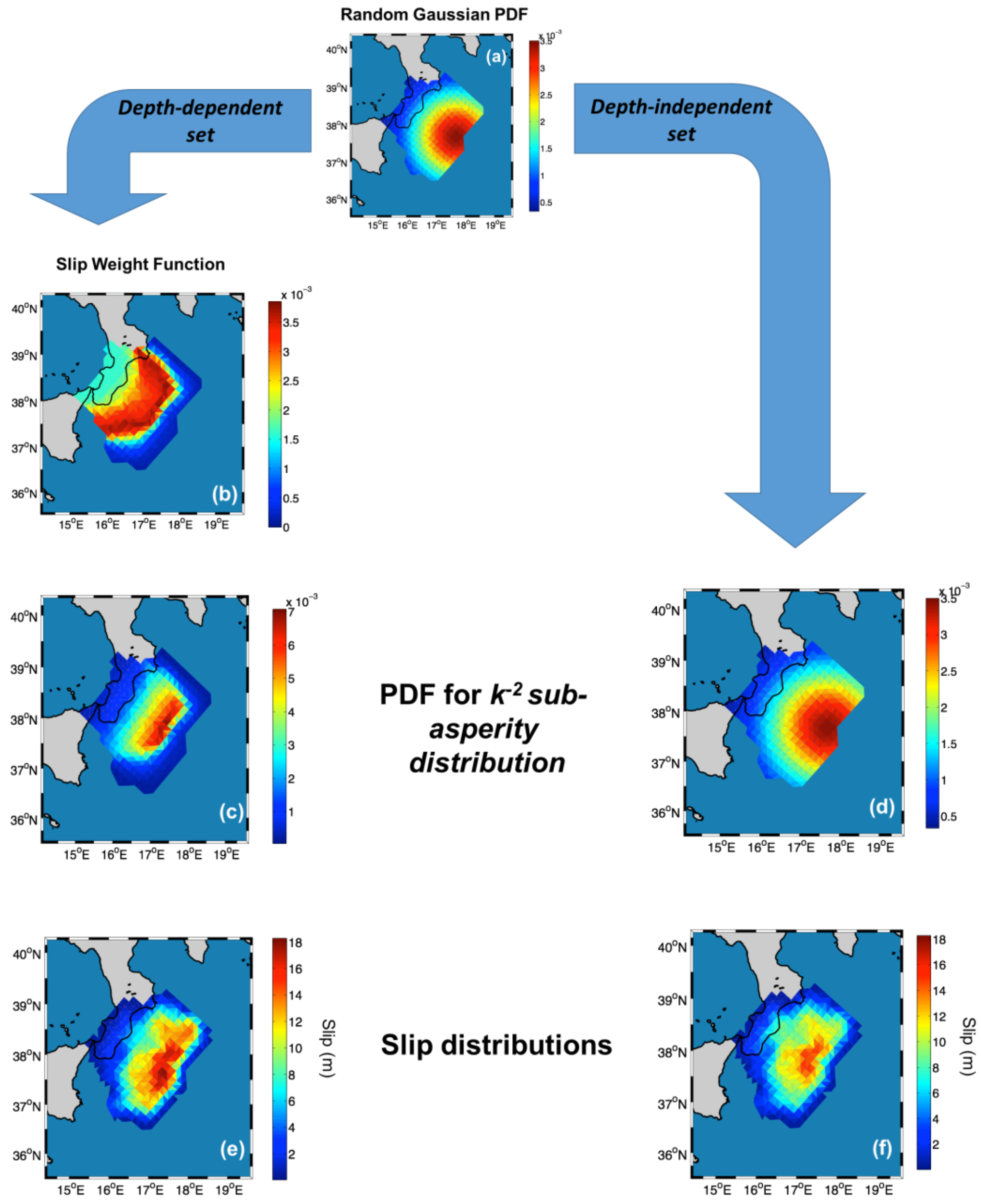
South Coral Patch Ridge Fault Rupture model:

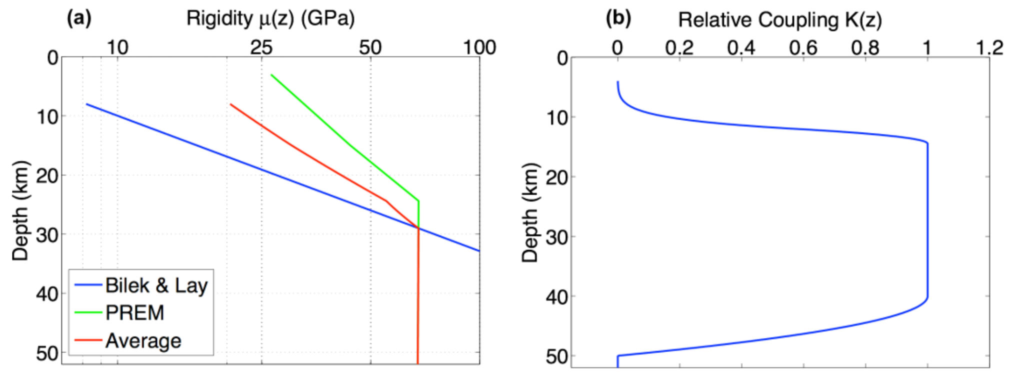
- strike 63° dip 22° rake 94°
- LxW 35x13 km, Z 6.6 km, slip 2 m
- Mw 7.5

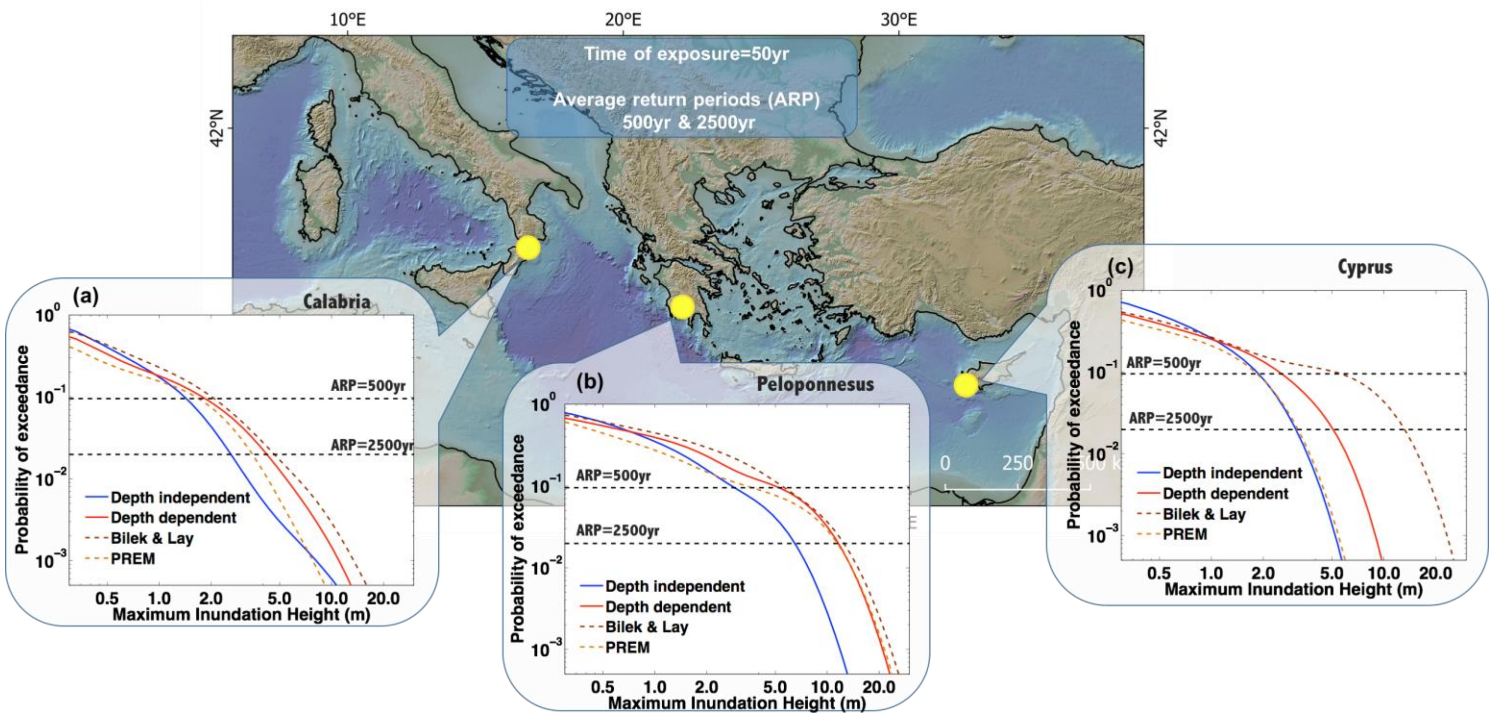




Seismic sources: rupture models – heterogeneous slip distribution







Scala et al. (2019, PAGEOPH)

Hints for the AGITHAR Working Groups

STEP 1 — **Probabilistic earthquake model**

Levels:

- Regionalization and seismic datasets
- Magnitude-Frequency Distribution (MFD)
- Earthquake rupture parameters for different seismicity modeling types for each magnitude of the MFD

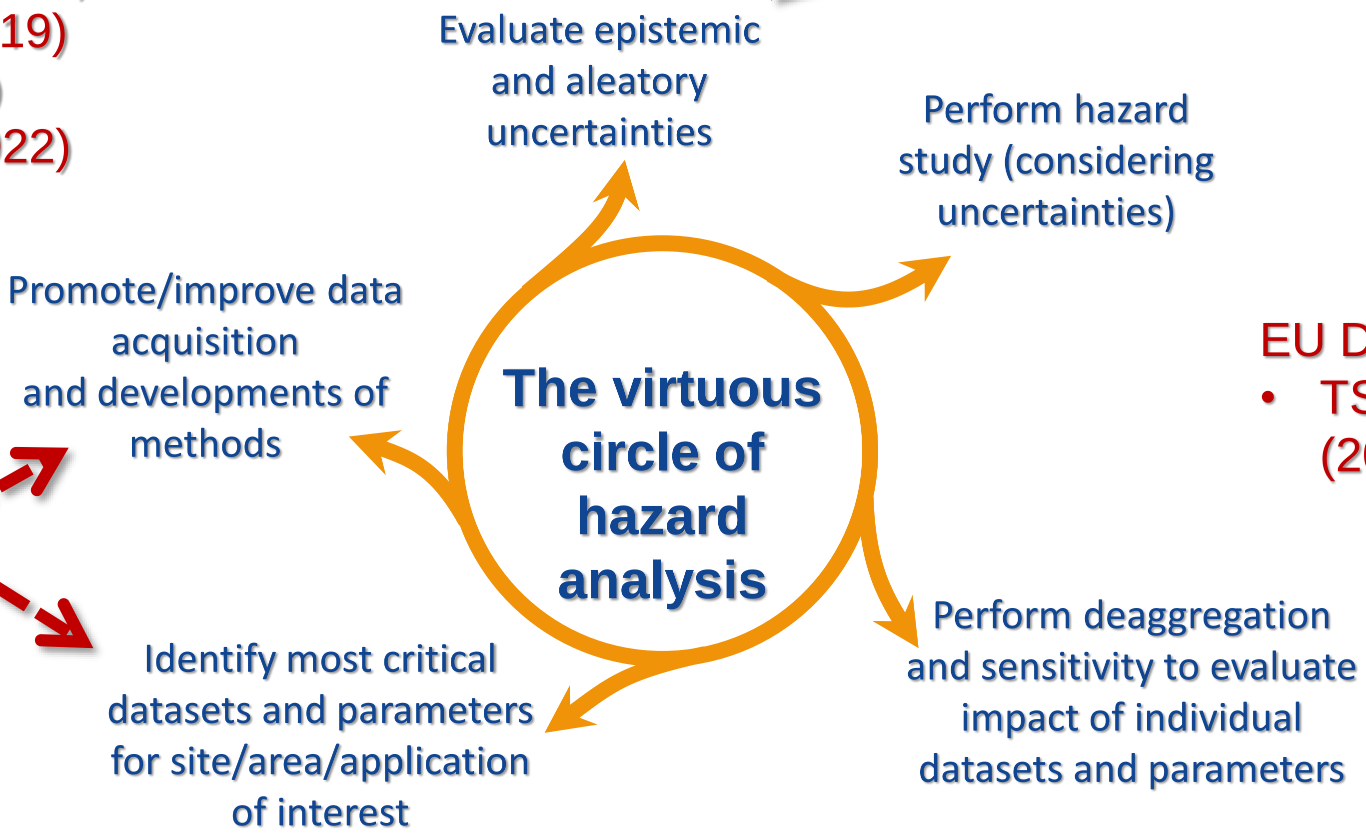
SSHAC guidelines: “**CBR of the ITC**”

“Regardless of the scale of the **PSHA** study the goal remains the same: to represent the **center**, the **body**, and the **range** that the larger **informed technical community** would have if they were to conduct the study” (NUREG/CR-6372).

- Earthquake rates and spatial distribution from smoothed seismicity only for BS
- Rupture scaling relationships used as “expected values” only
- Planar geometry for ruptures on BS
- Uniform slip distribution for ruptures on BS

- Adopt tectonic/geodetic rates for crustal earthquakes (BS)
- Increase variability of rupture scaling
- Extend the approach used for PS (3D geometry and heterogeneous slip) to as many crustal faults as possible

EU Projects
- TRANSFER (2006-2009)
- SHARE (2009-2012)
- STREST (2013-2016)
- ASTARTE (2013-2017)
- EPOS-IP (2015-2019)
- SERA (2018-2020)
- CHEESE (2019-2022)



EU DG-ECHO Project
- TSUMAPS-NEAM (2016-2017)

Project Partnership

COORDINATOR

INGV

PARTNERS

NGI

ipma

UNIBA
Centro Universitario
Internacional
de Barcelona

METU

GFZ
Helmholtz Centre
POTSDAM

Institut National de la Meteorologie

ΕΘΝΙΚΟΝ ΑΣΤΕΡΟΣΚΟΠΕΙΟΝ ΑΘΗΝΩΝ
NATIONAL OBSERVATORY ATHENS

CNRST