IOC/UNESCO Information Meeting on NEAMTWS

Madrid,25/09/2017

Roberto Basili & TSUMAPS-NEAM Team

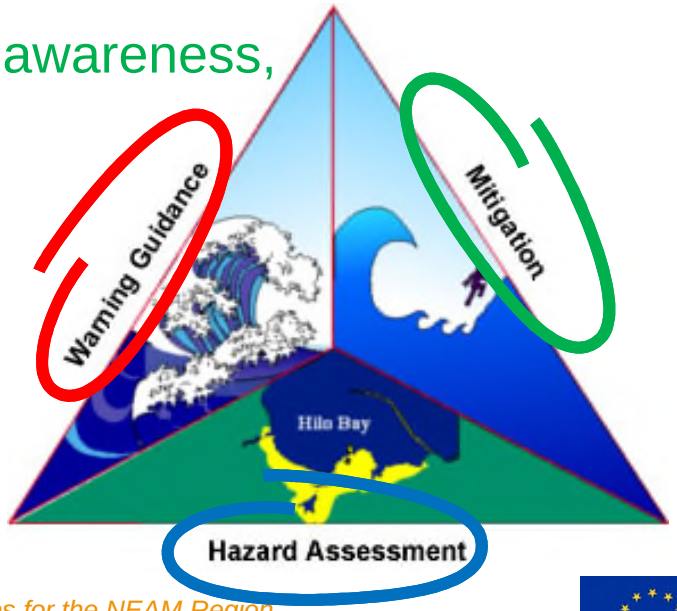
Summary of results from the TSUMAPS-NEAM project

Co-funded by the
European-Union Civil Protection Mechanism

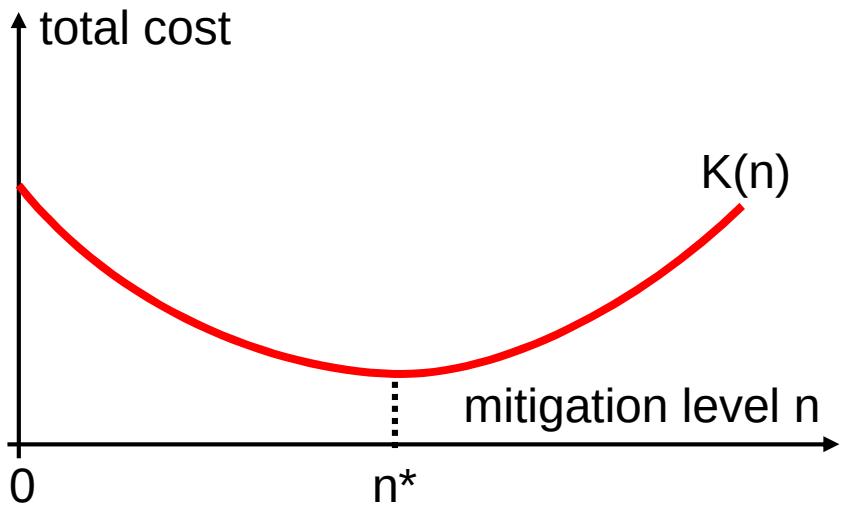
Agreement Number:
ECHO/SUB/2015/718568/PREV26

NEAM = North-East Atlantic, the Mediterranean, and connected Seas

- Tsunamis are **Low Probability / High Consequences** natural events
- **Europe** is a **highly exposed** region (populated coastlines, critical infrastructures, etc.)
- Tsunami Early Warning has been implemented within the IOC-UNESCO ICG/NEAMTWS framework
- A region-wide Tsunami Hazard (and consequently Risk) Assessment is still unavailable in the NEAM region
- This weakens any Mitigation Action (lack of awareness, coastal planning, risk reduction for critical infrastructures, NEAMTWS last mile and evacuation plans, etc.)



Why do we need good hazard estimations?



“Variation in total cost, the sum of expected loss and mitigation cost, as a function of mitigation level. The optimal level of mitigation, n*, minimizes the total cost. The expected loss depends on the hazard model, so the better the hazard model, the better the mitigation policy.”

[Stein and Stein, 2012, GSA Today]

What type of hazard estimations do we need?

Examples of earthquake decisions

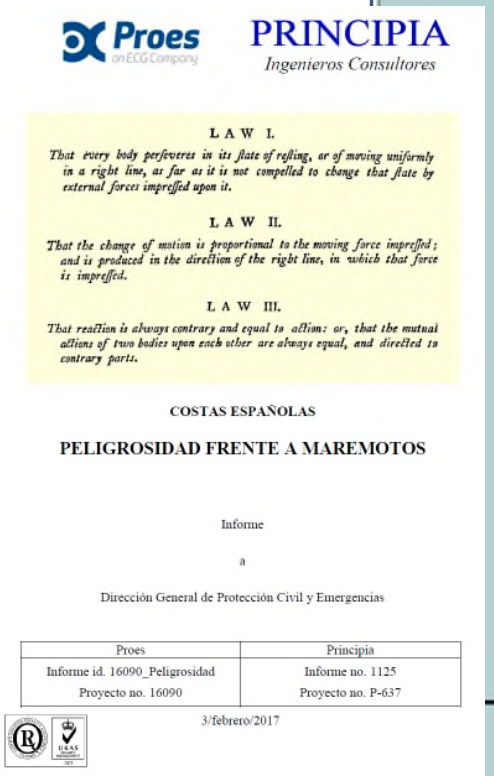
Decision	Quantitative aspects of decision	Predominant approach
Seismic design levels	Highly quantitative	Probabilistic
Retrofit design	Highly quantitative	Probabilistic
Insurance/reinsurance	Highly quantitative	Probabilistic
Design of redundant industrial systems	Quantitative or qualitative	Both
Training and plans for emergency response	Mostly qualitative	Deterministic
Plans for post-earthquake recovery	Mostly qualitative	Deterministic
Plans for long-term recovery, local	Mostly qualitative	Deterministic
Plans for long-term recovery, regional	Mostly quantitative	Probabilistic

"…complementary nature of deterministic and probabilistic analyses: deterministic events can be checked with a probabilistic analysis to ensure that the event is realistic (and reasonably probable), and probabilistic analyses can be checked with deterministic events to see that rational, realistic hypotheses of concern have been included in the analyses."

[McGuire, 2001, SoilDynEqEng]

Directriz Básica de Planificación de Protección Civil Ante el Riesgo de Maremotos Real Decreto 1053/2015

→ **National Tsunami Hazard Map**



Proes an ECG Company

PRINCIPIA
Ingenieros Consultores

L A W I.

That every body perſeveres in its ſtate of reſting, or of moving uniformly in a right line, as far as it is not compelled to change that ſtate by external forces impreſſed upon it.

L A W II.

That the change of motion is proportional to the moving force impreſſed; and is produced in the direction of the right line, in which that force is impreſſed.

L A W III.

That reaction is always contrary and equal to action: or, that the mutual actions of two bodies upon each other are always equal, and directed to contrary parts.

COSTAS ESPAÑOLAS

PELIGROSIDAD FRENTE A MAREMOTOS

Informe

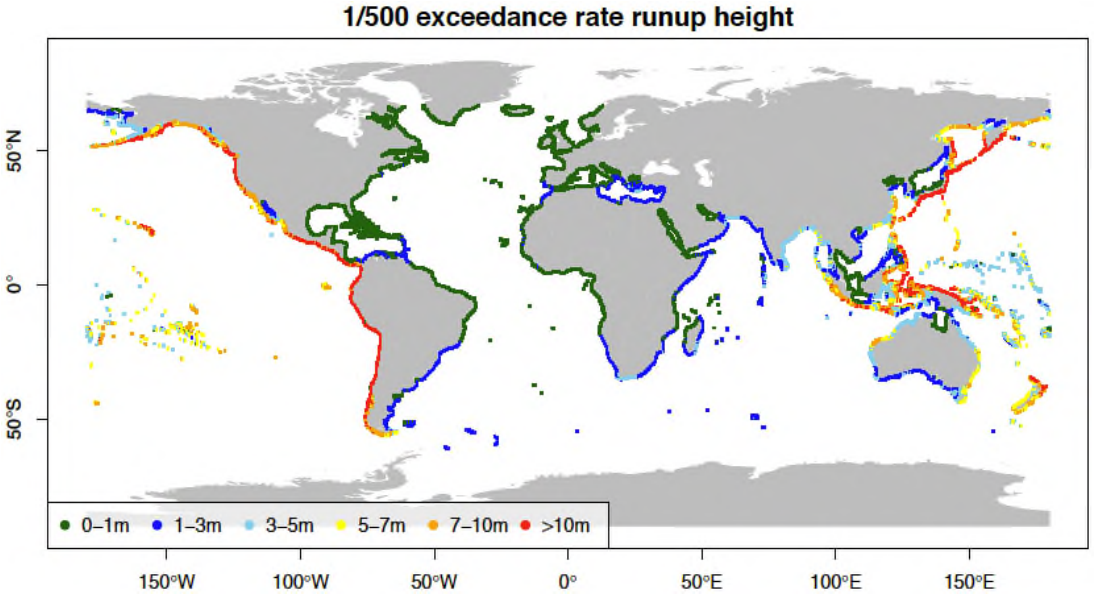
a

Dirección General de Protección Civil y Emergencias

Proes	Principia
Informe id. 16090_Peligrosidad	Informe no. 1125
Proyecto no. 16090	Proyecto no. P-637

3/febrero/2017

Existing region-wide PTHA models



Global Models:

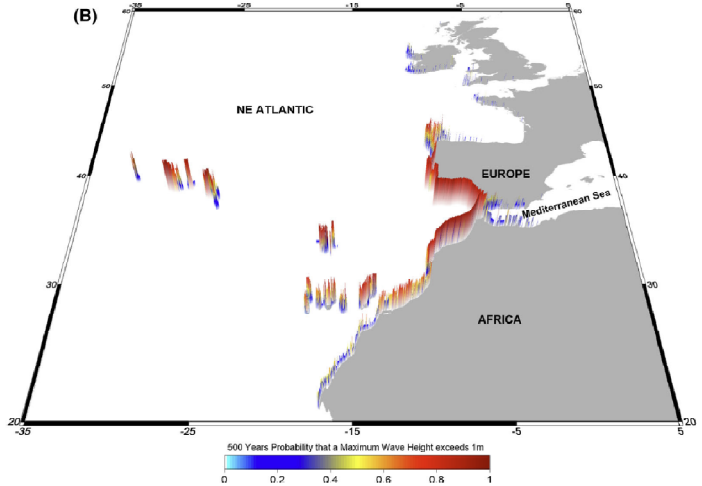
GFDRR GAR15

Davies et al., 2017, GSL

includes epistemic uncertainties

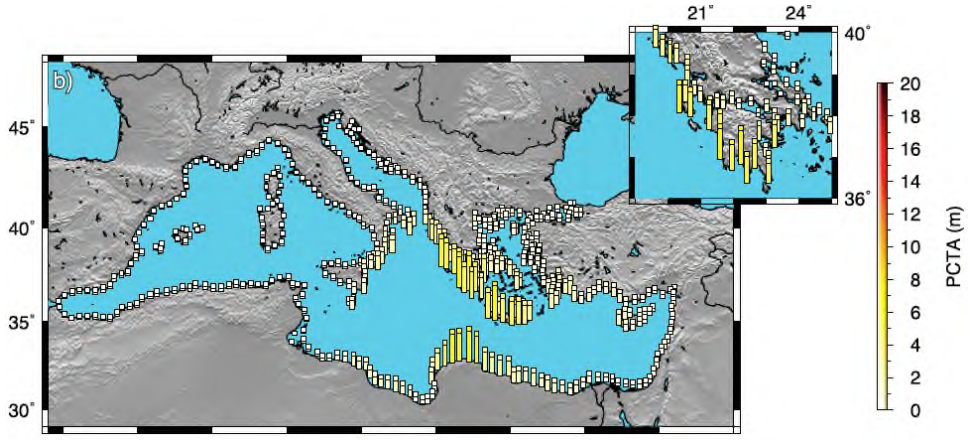
Regional Model for the **North-East Atlantic**

Omira et al., 2015, PAGEOPH

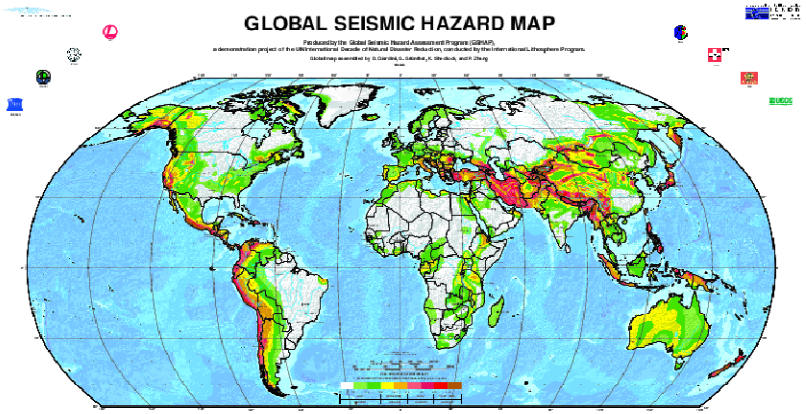


Regional Model for the **Mediterraenan**

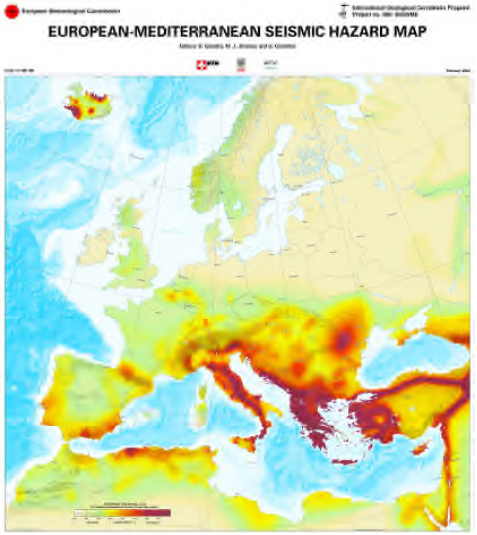
Sørensen et al., 2012, JGR



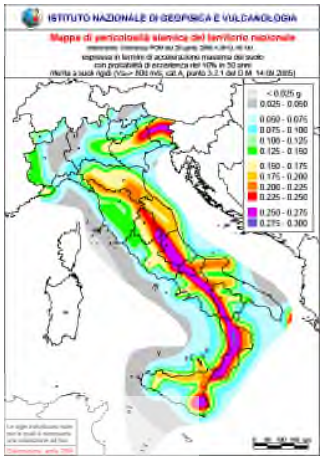
What does science do for seismic hazard (PSHA)?



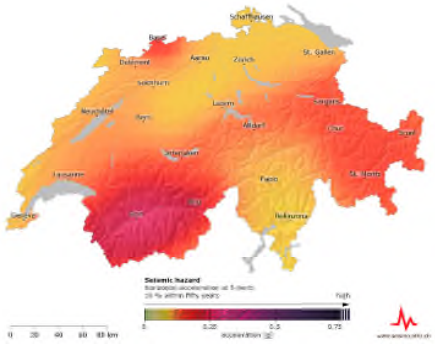
GSHAP 1999



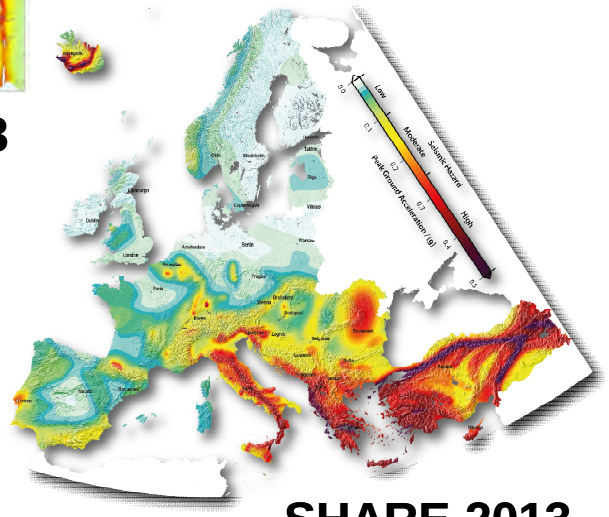
SESAME 2003



Italy
MPS04, 2004



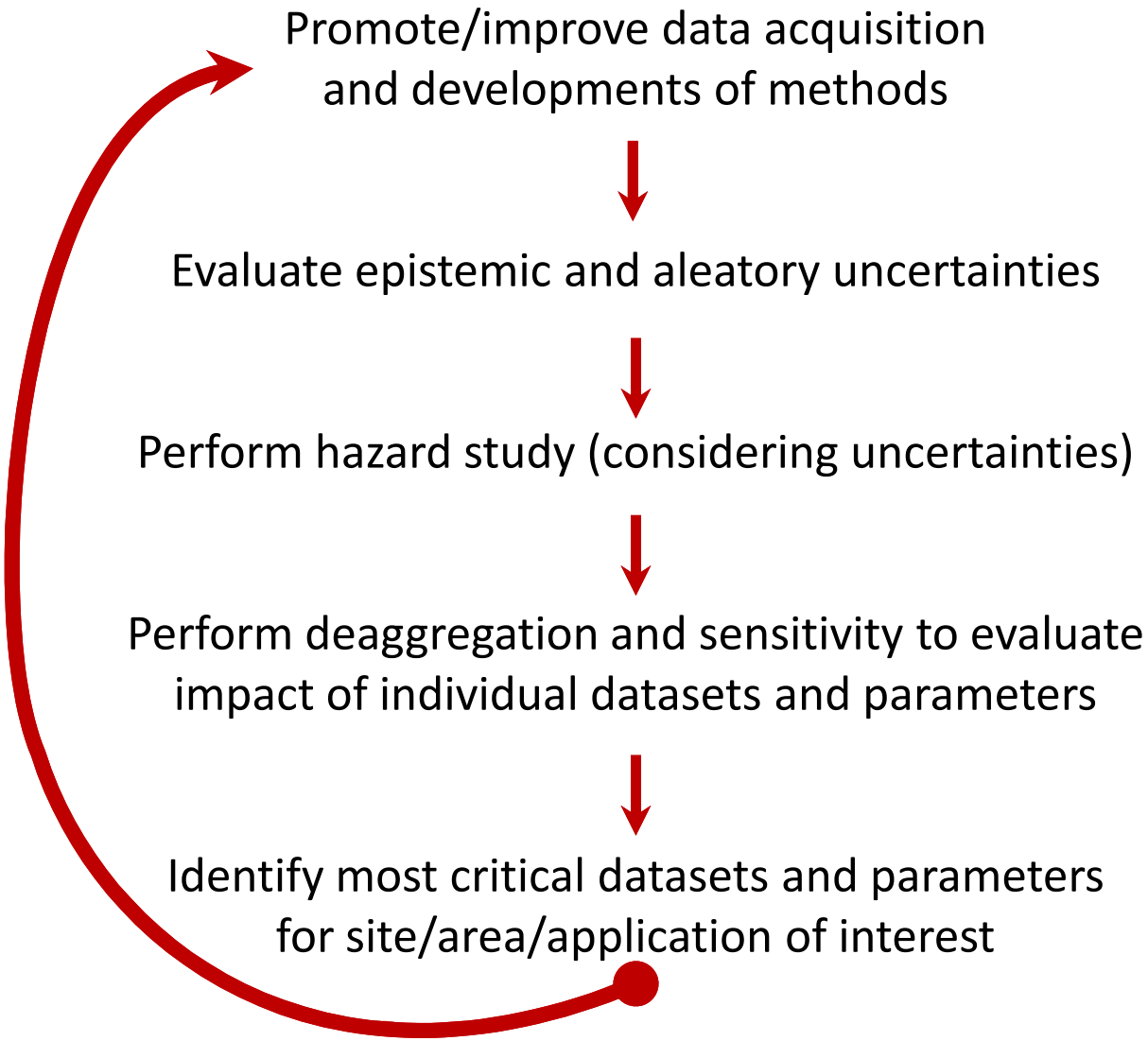
Switzerland
SUIhaz15, 2015



SHARE 2013

SERA 2019?

The virtuous circle in hazard analysis



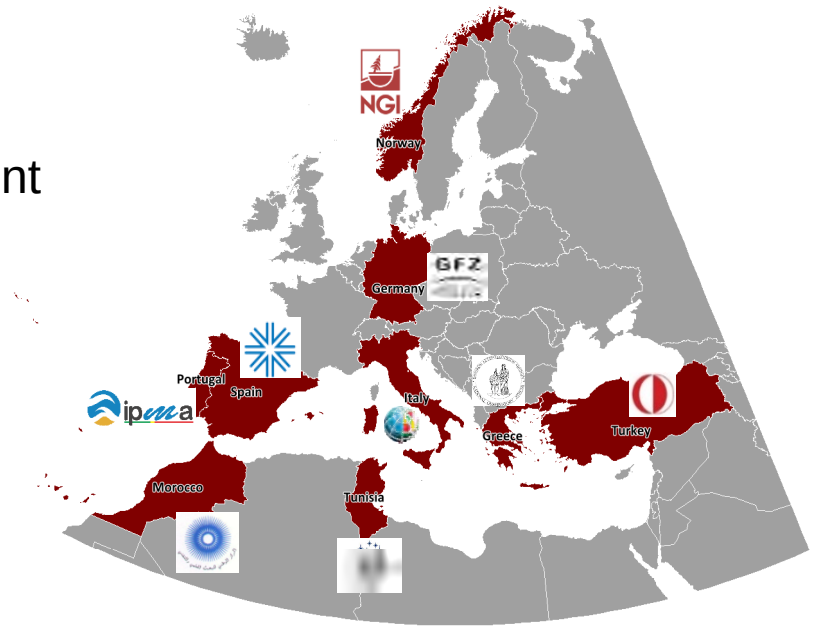
The project at a glance (http://www.tsumaps-neam.eu/)

TSUMAPS-NEAM project objectives:

- produce the first region-wide long-term homogenous PTHA for NEAM;
- trigger a common tsunami risk management strategy in the region.

Funded by European Union Humanitarian Aid & Civil Protection

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



INGV	NGI	IPMA	GFZ	METU	UB	NOA	CNRST	INM
Basili R. Lorito S. Selva J.	Harbitz C.B. Løvholt F.	Baptista M. A. Matias L. Omira R.	Babeyko A.	Yalciner A. Pekcan O.	Canals M. Lastras G.	Papadopoulos G.	Benchekroun S.	Ben Abdallah S.
Italy	Norway	Portugal	Germany	Turkey	Spain	Greece	Morocco	Tunisia
Member State	Participating State	Member State	Member State	Enlargement	Member State	Member State	Neighborhood Policy	Neighborhood Policy

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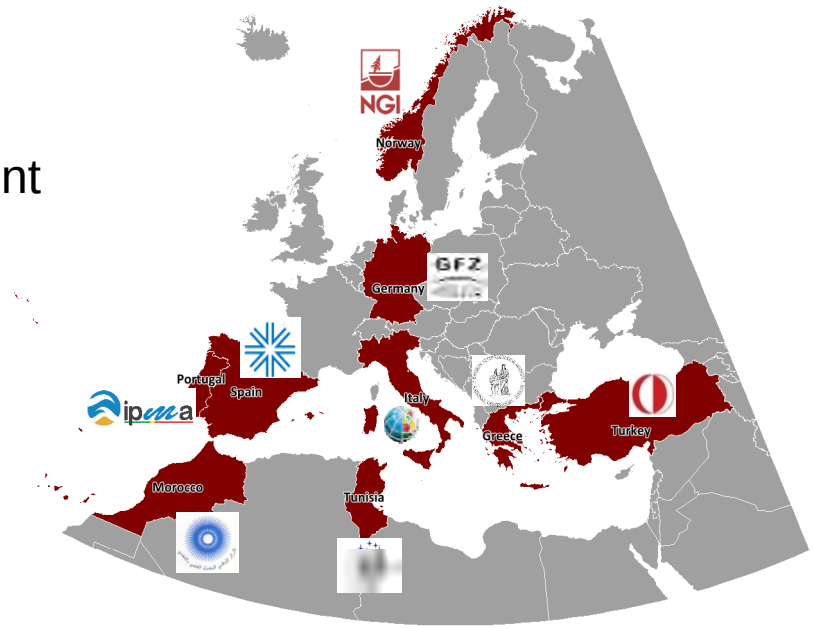

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End Users and Advisers

EWS-CARIBE

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

UNESCO

SRB-RAS

PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

USGS science for a changing world

EPOS

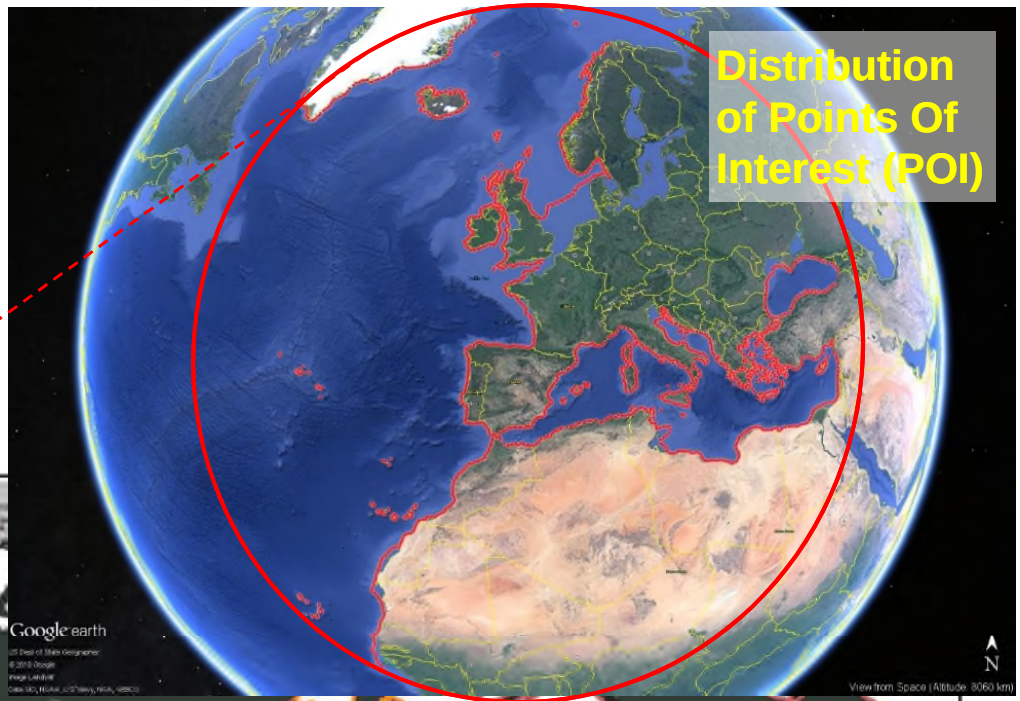
National Institute of Oceanography & Fisheries

BOĞAZİÇİ UNIVERSITY
KANDİLLİ OBSERVATORY and EARTHQUAKE RESEARCH INSTITUTE

Target coastlines (NEAMTWS)

TSUMAPS-NEAM target coastlines are those of the NEAMTWS in Area of Coverage Map of ICGS, IOC-UNESCO

Distribution of POIs
North-East Atlantic: 1076
Mediterranean Sea: 1130
Black Sea: 137
Average spacing ~ 20 km



Working Group on Tsunamis and Other Hazards Related to Sea-Level Warning and Mitigation Systems (TOWS-WG)
Eighth Meeting Morioka, Japan 12–13 March 2015

Starting points

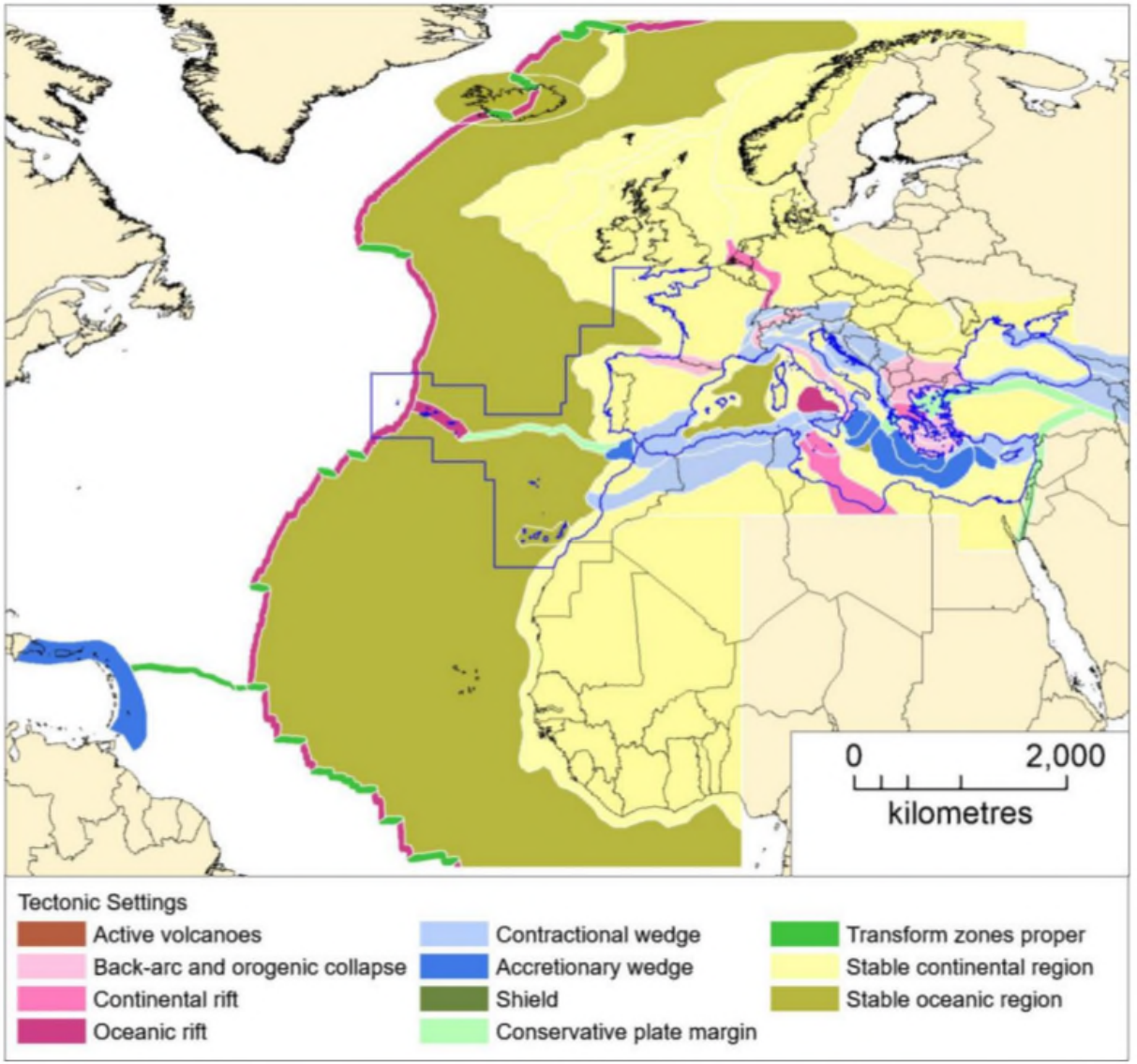
- Treatment of all seismic sources without pre-selections
  - → Probabilistic approach
  - → Earthquakes possible everywhere

- Use of all the available information
  - →Well known sources should have special treatment
  - →Controlled simplifications according to scale & computational feasibility

- Quantification of the epistemic uncertainty
  - → Variability within scientifically acceptable models
  - → Community distribution & ensemble model

- Transparent treatment of subjectivity of choices
  - → Multiple-Expert Management protocol

Sources

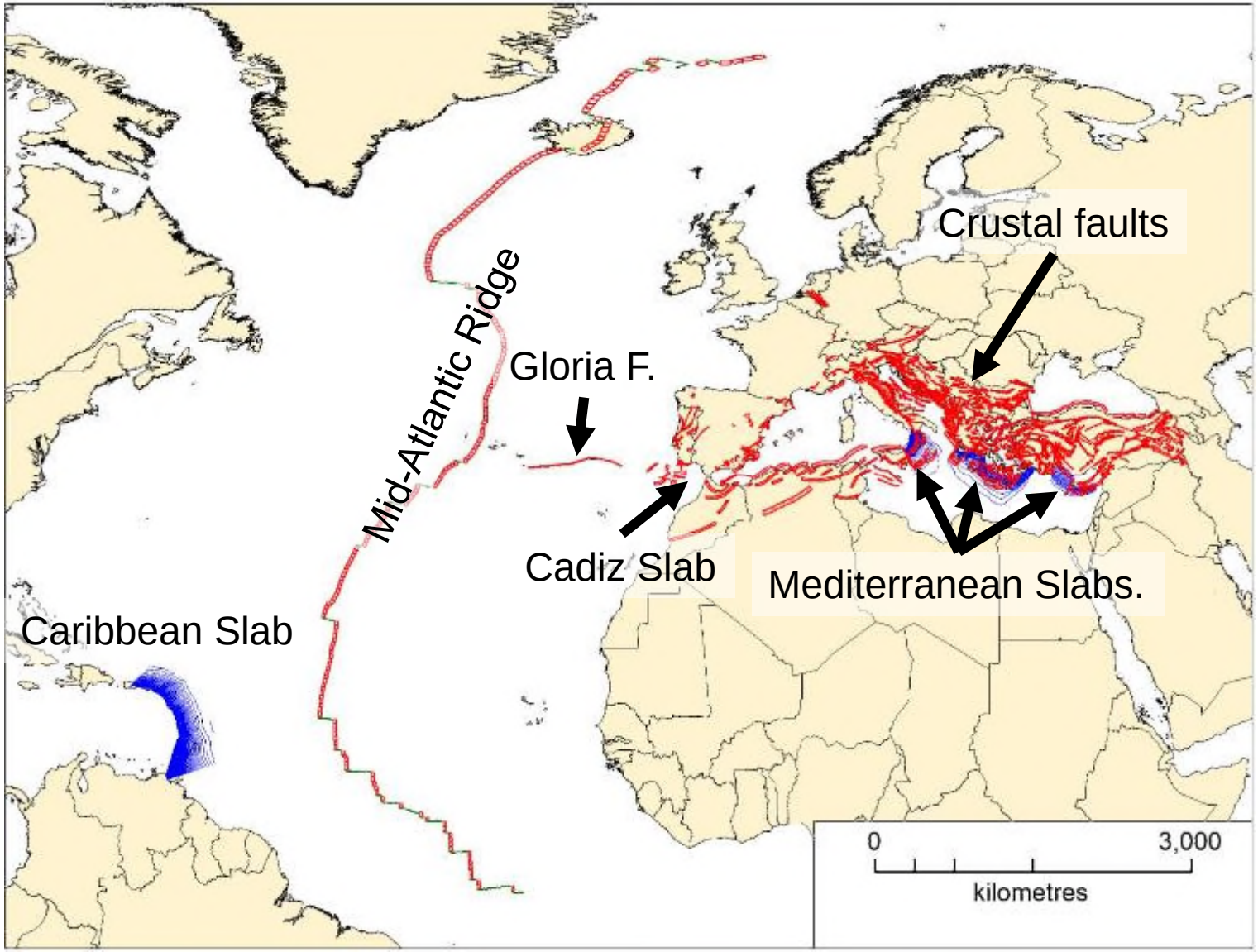

0
2,000
kilometres
Tectonic Settings
Active volcanoes
Back-arc and orogenic collapse
Continental rift
Oceanic rift
Contractional wedge
Accretionary wedge
Shield
Conservative plate margin
Transform zones proper
Stable continental region
Stable oceanic region

Types of sources

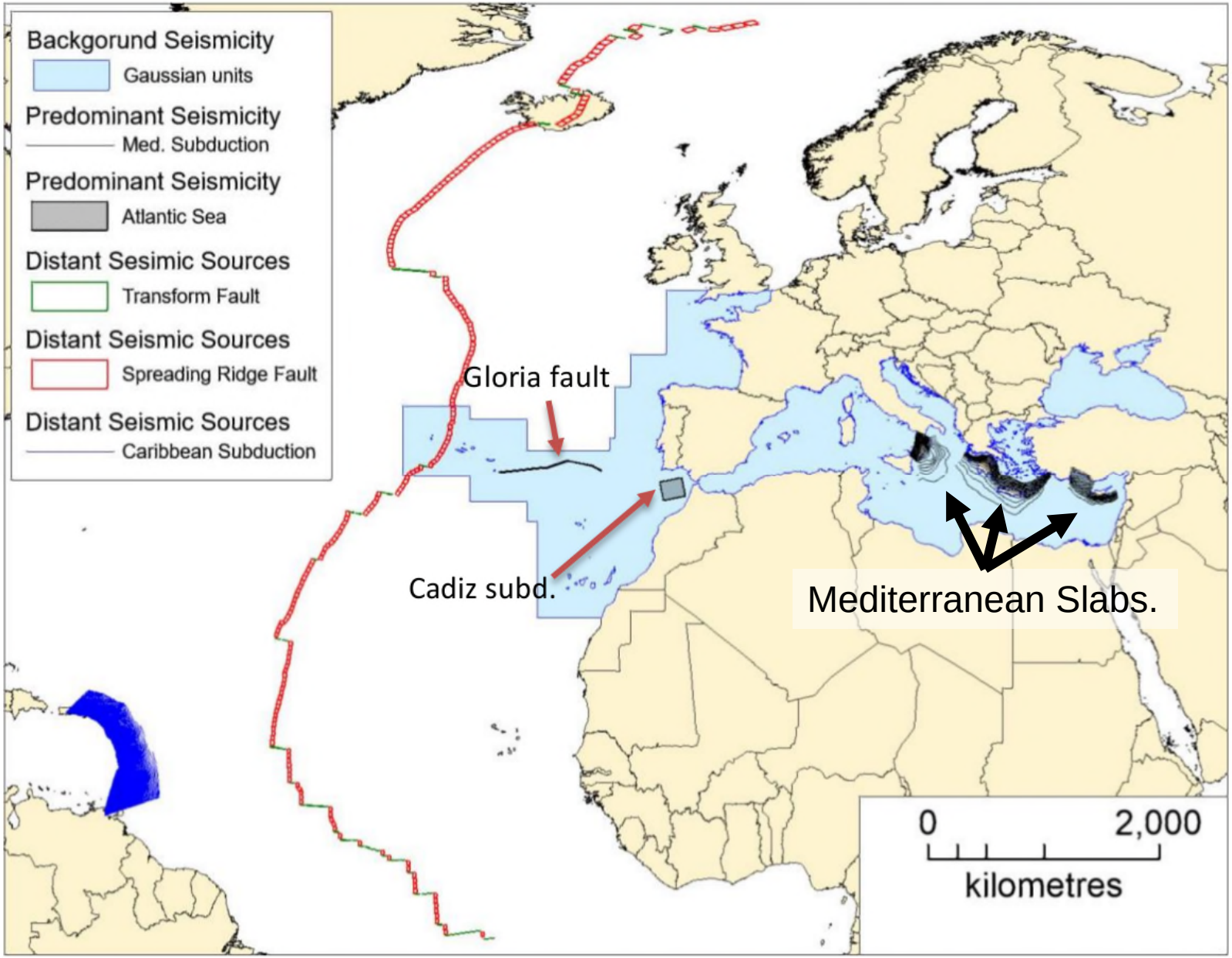
- Prevalent Seismicity
  - 3D geometry & Slip distribution
  - Main source of tsunamis, typically in well-known sources
- Background Seismicity
  - Planar faults and uniform slip
  - Everywhere with all geometries
- Special Background Seismicity
  - Planar faults and uniform slip
  - Important sources only partially known → limited variability

→ Different levels of details in modelling
→ Use of all the available information to reduce dispersion
→ Different extensions, depending on distance source-targets

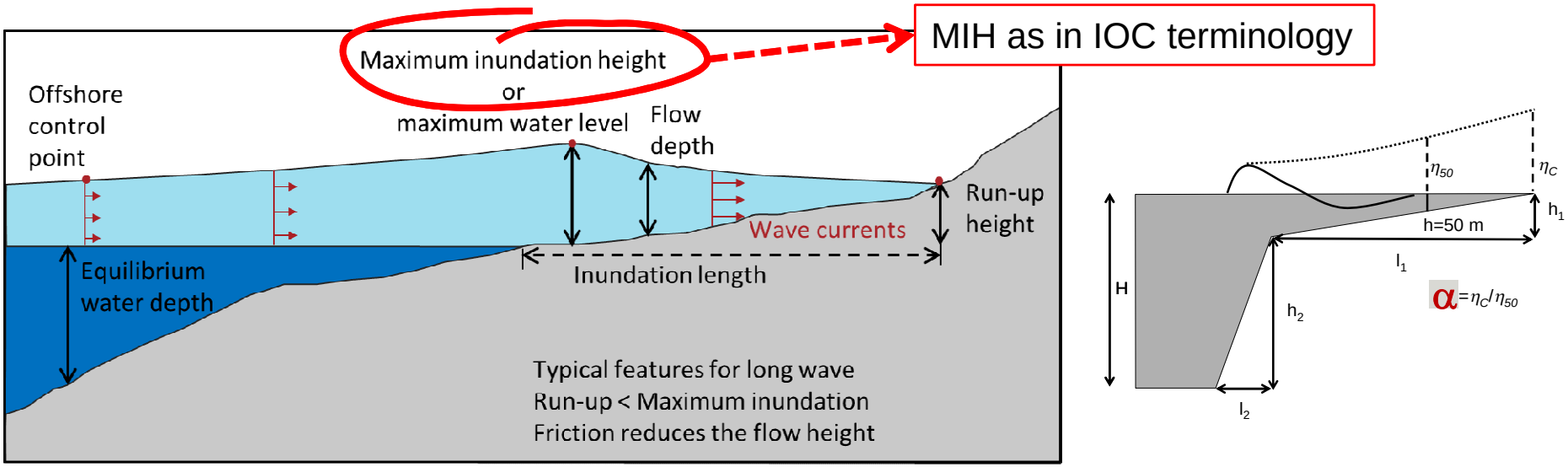
Types of sources

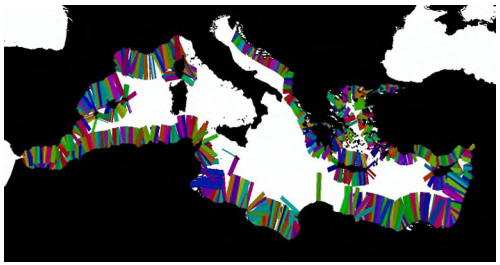


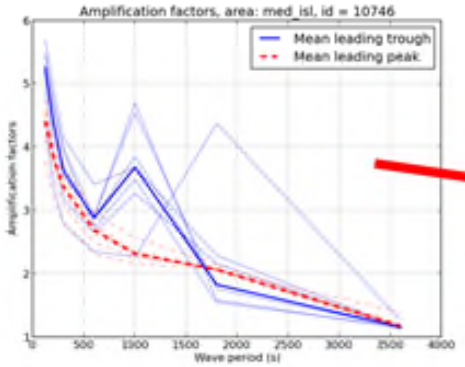
Types of sources

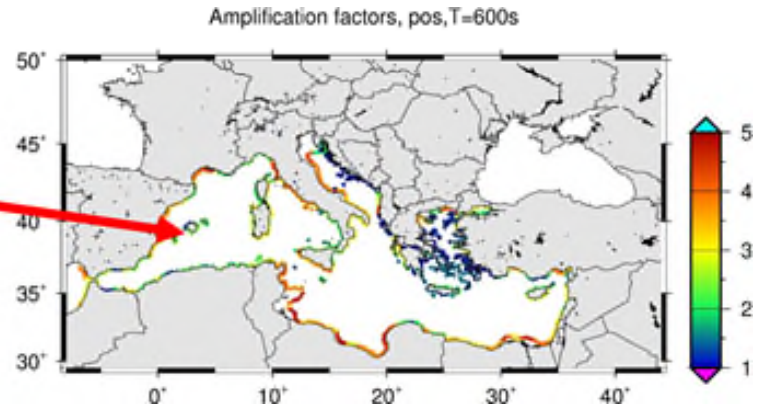


Tsunami hazard metrics









For a given target point - extract 40 nearby depth profiles

Run the 1HD LSW model for all combinations of the wave characteristics (polarity and period) for a selection of profiles

For each run: measure surface elevation at 50 m depth and shoreline, compute the amplification factors

Use the median value of the amplification factor over all the simulated transects for each wave period

Store results (median amplification factor values) in a look-up table

Multiply factors with 2HD simulations results to compute the MIH

- ***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***

The same methodology is also being used for

→ *Italian National PTHA mapping*
→ *Support for Definition of evacuation zones (Italian Tsunami Warning System)*

→ *Guidelines and Standards for Tsunami Hazard and Risk to be developed by the*

GLOBAL TSUNAMI MODEL (GTM, www.globaltsunamimodel.org)

INGV terremoti vulcani ambiente
ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

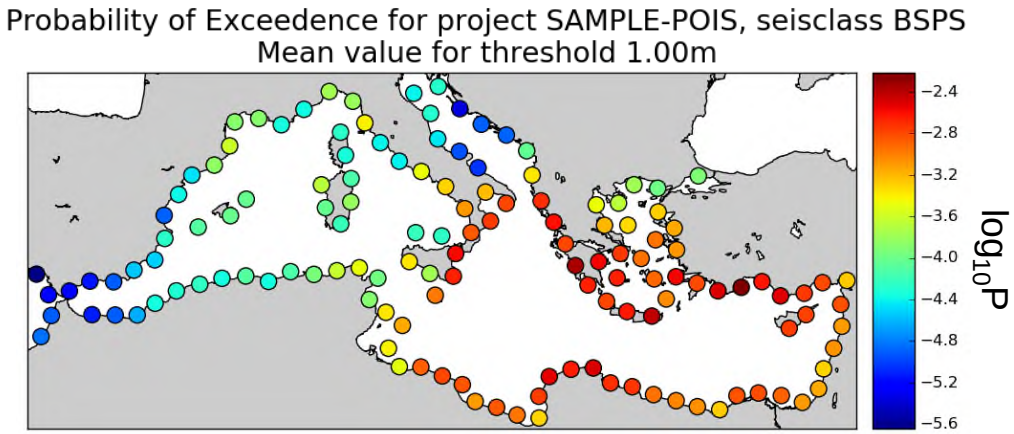
GTM globaltsunamimodel

A transparent way to manage subjectivity

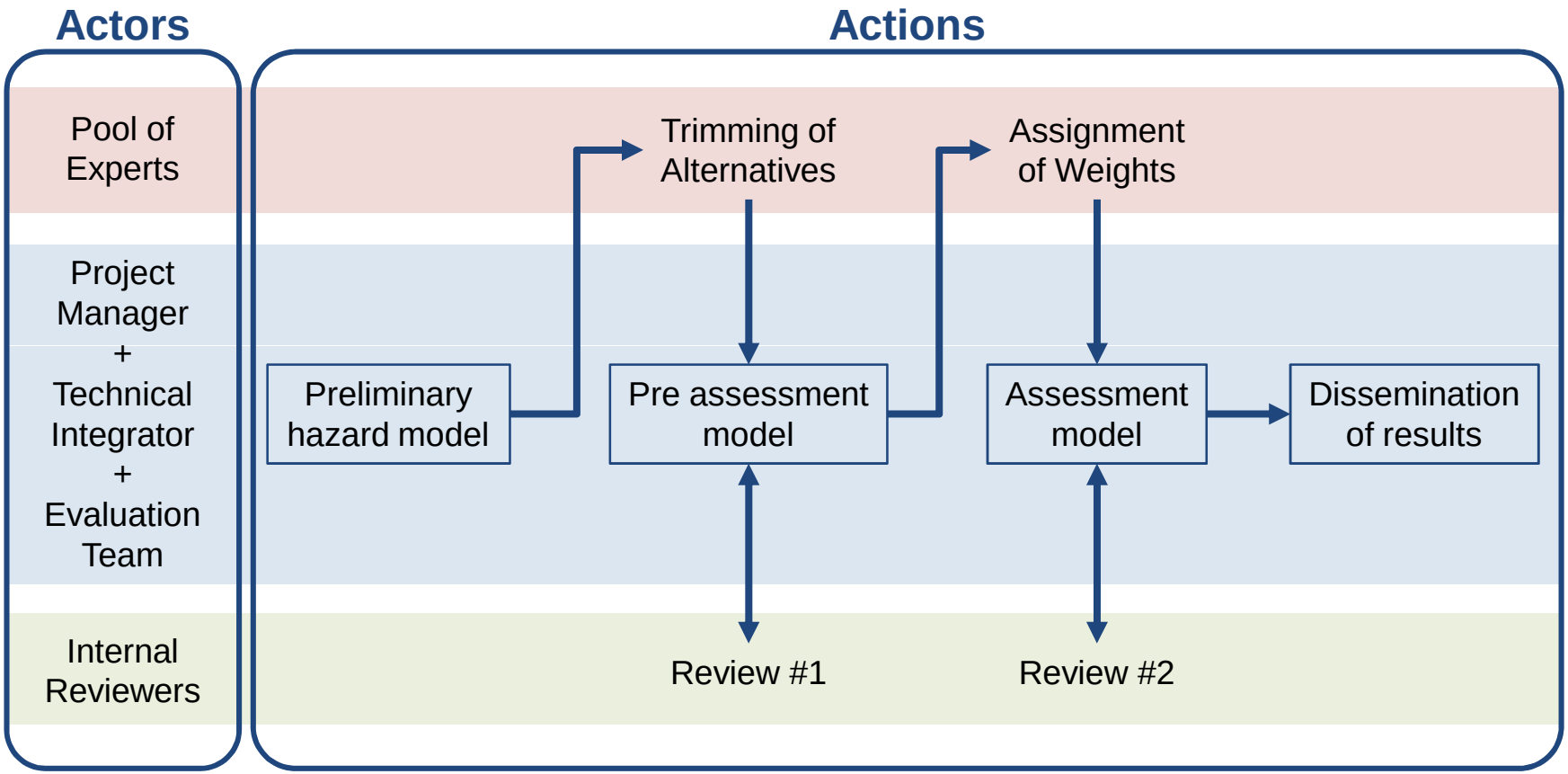
TSUMAPS-NEAM multi-expert process for uncertainty quantification

In a nutshell, the purpose of the protocol is:

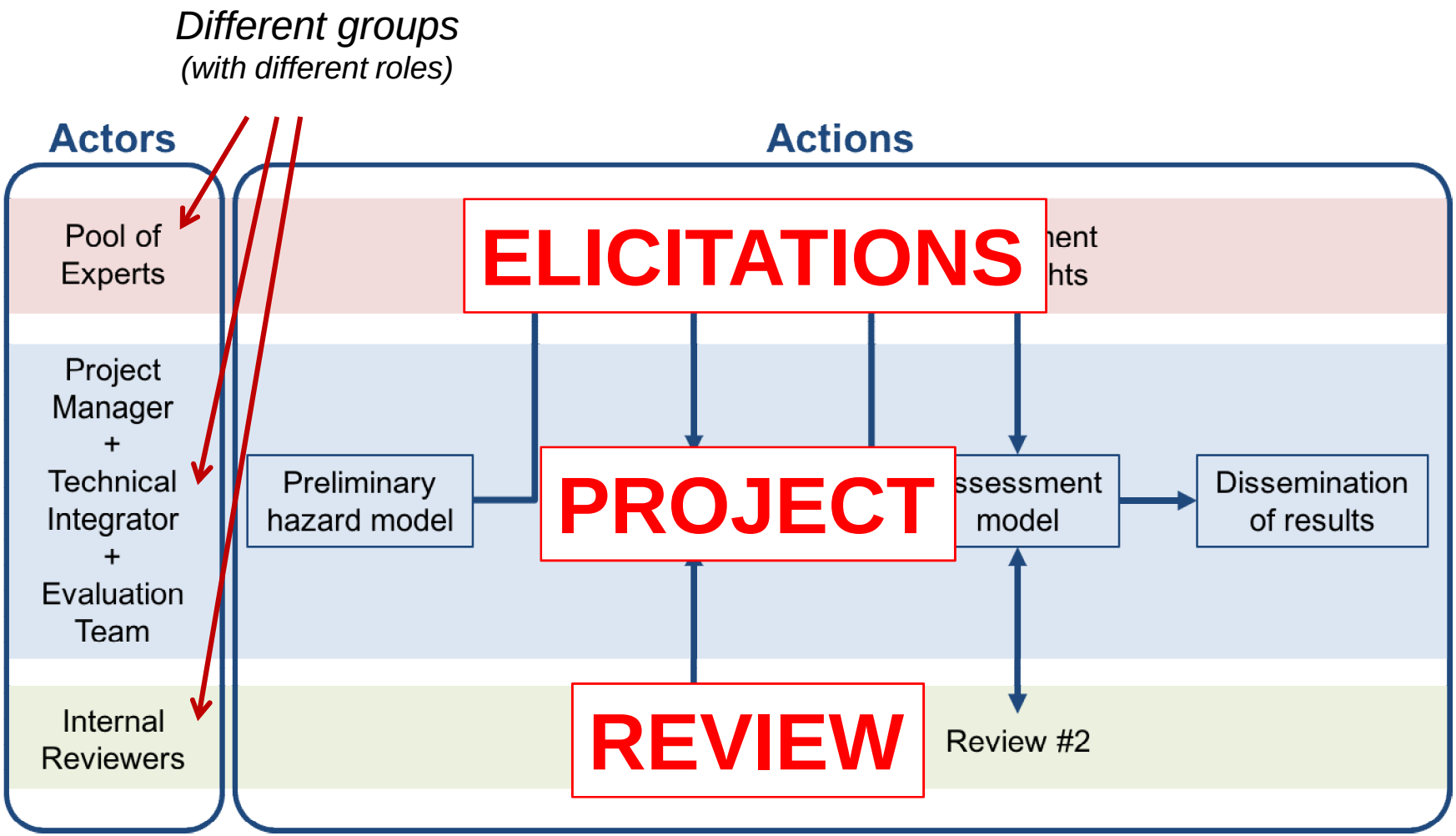
1. To establish roles and responsibilities, in order to guarantee **transparency, independency of roles, accountability and achievement of procedural consensus**;
2. To homogenize the management of decision making for subjective choices, guaranteeing **documented and traceable decision making**;
3. To establish **homogeneous principles for the management of alternatives**, that is, **alternative and scientifically acceptable implementations for quantifying the community distribution**.



Multi-expert integration process



Multiple-Expert Management Protocol



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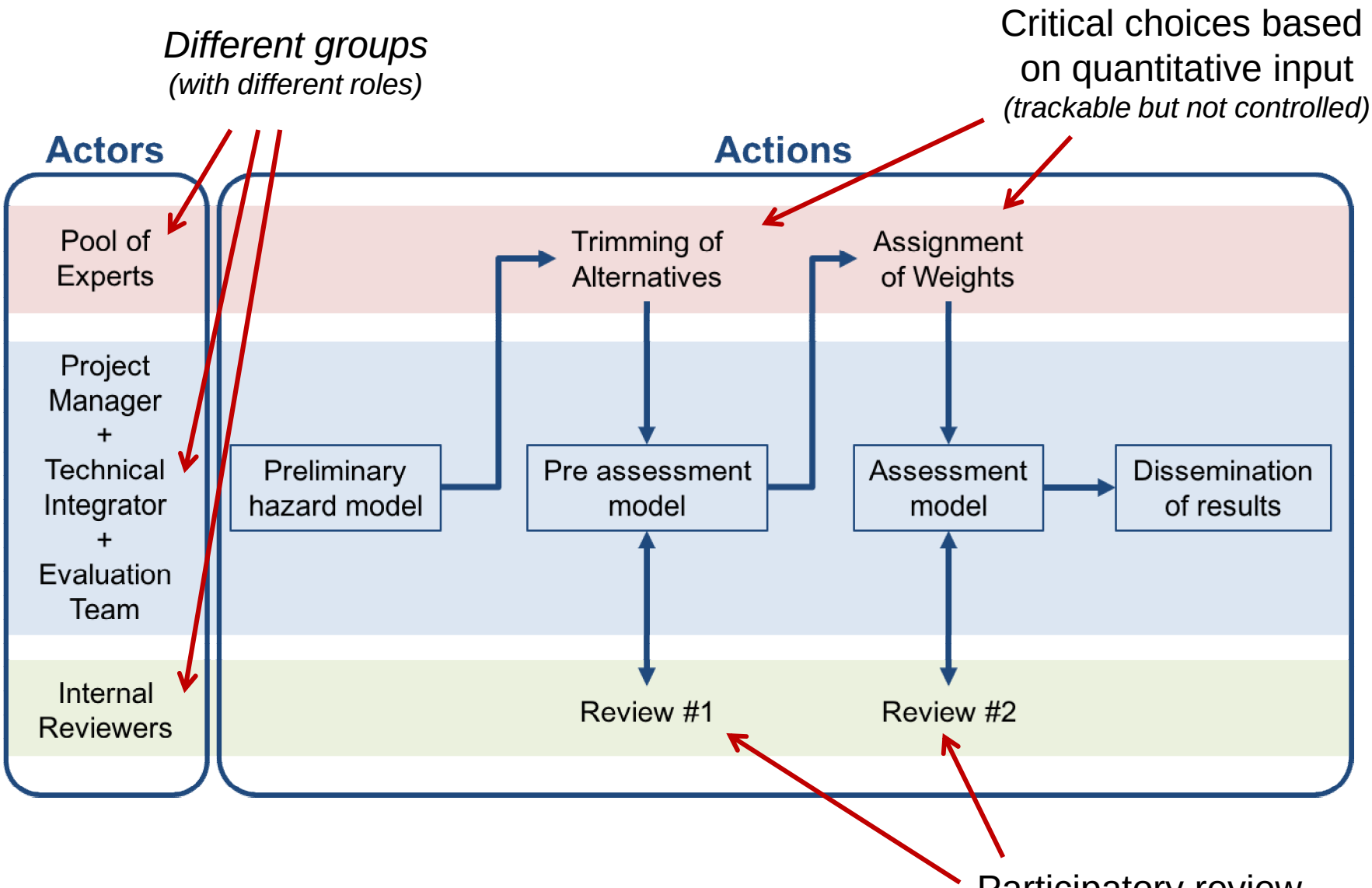


Hazard results

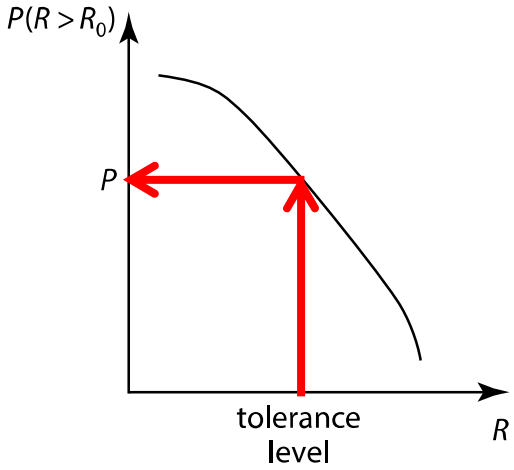
- Hazard curves calculated at 2,343 POIs (North-East Atlantic: 1,076; Mediterranean Sea: 1,130; Black Sea: 137) at an average spacing of ~ 20 km
- For each curve, hazard values for mean, 2nd, 16th, 50th, 84th, 98th percentiles.
- Probability maps for MIH 0.5, 1, 5, 10, 20 meters
- Hazard maps for 1/100 years; 1/1,000 years; 1/10,000 years RI
- Interactive Hazard Map and Curve Tool

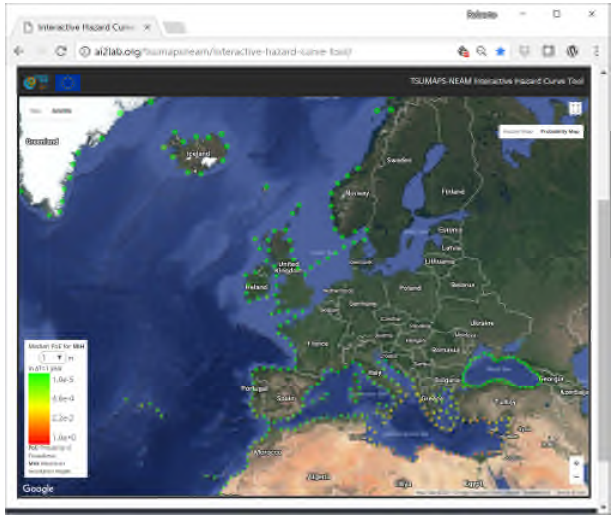
By-products

- 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

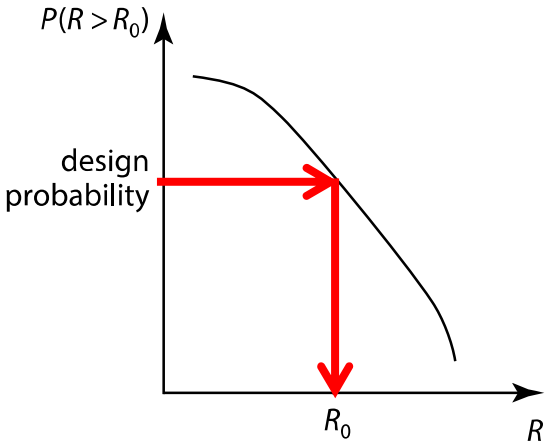
HPC supported by

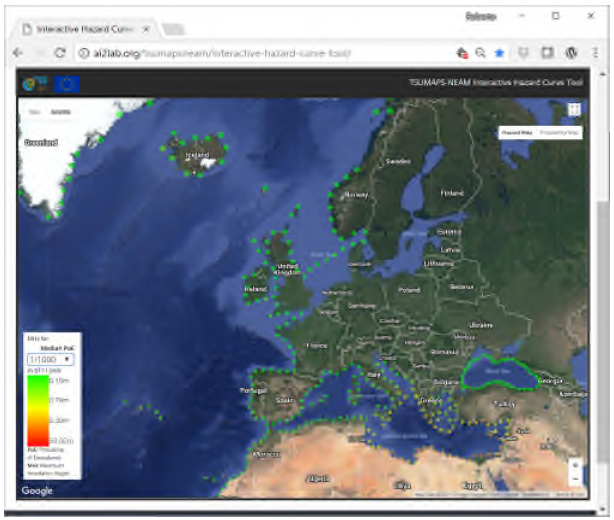
select tolerance level >>> display probability map



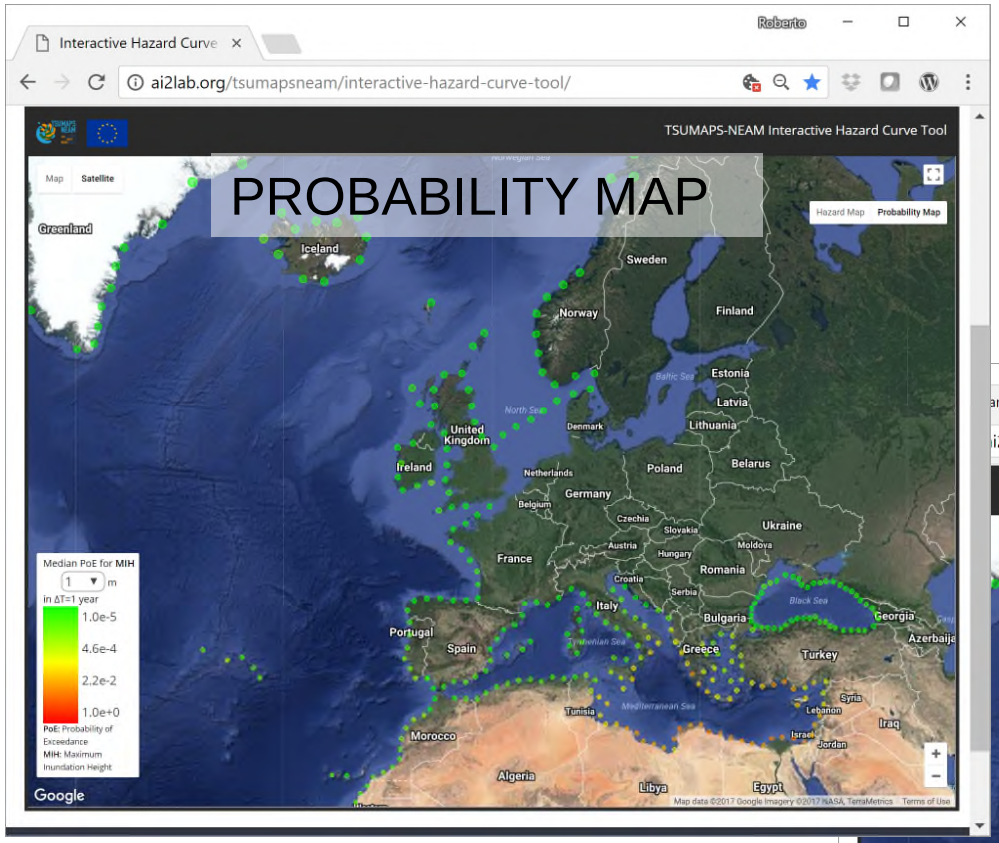


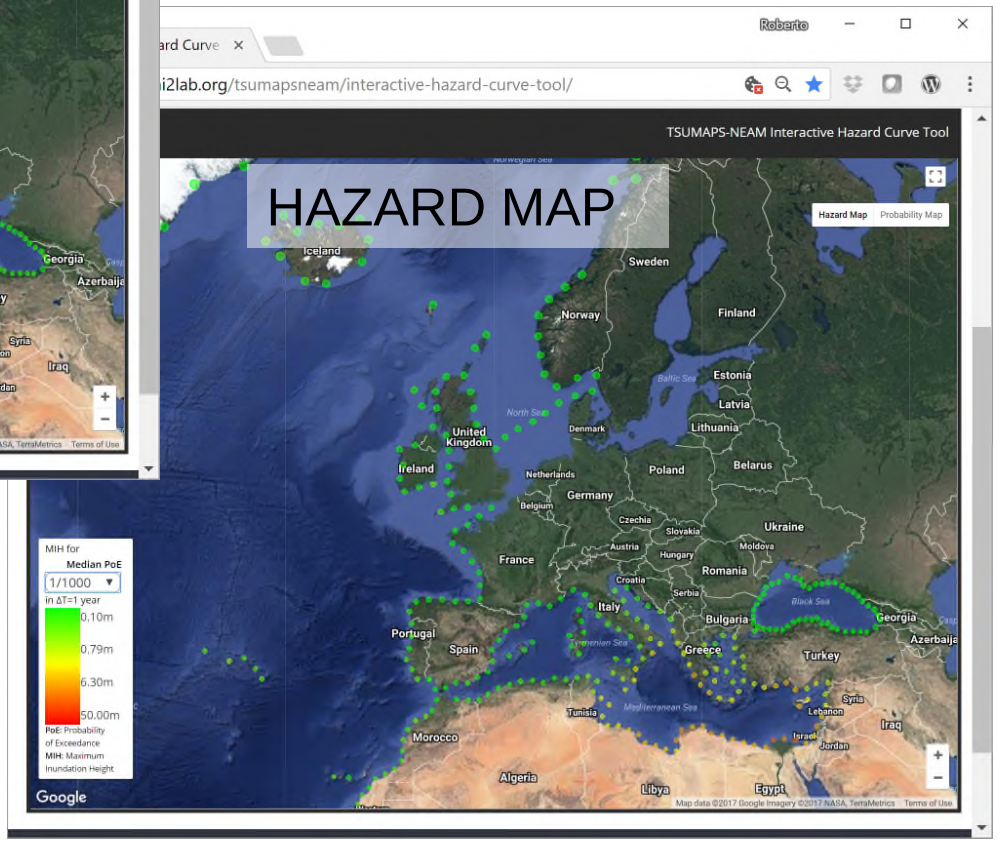
select design probability >>> display hazard map





Results: Probability and Hazard Maps





Probability and Hazard Maps

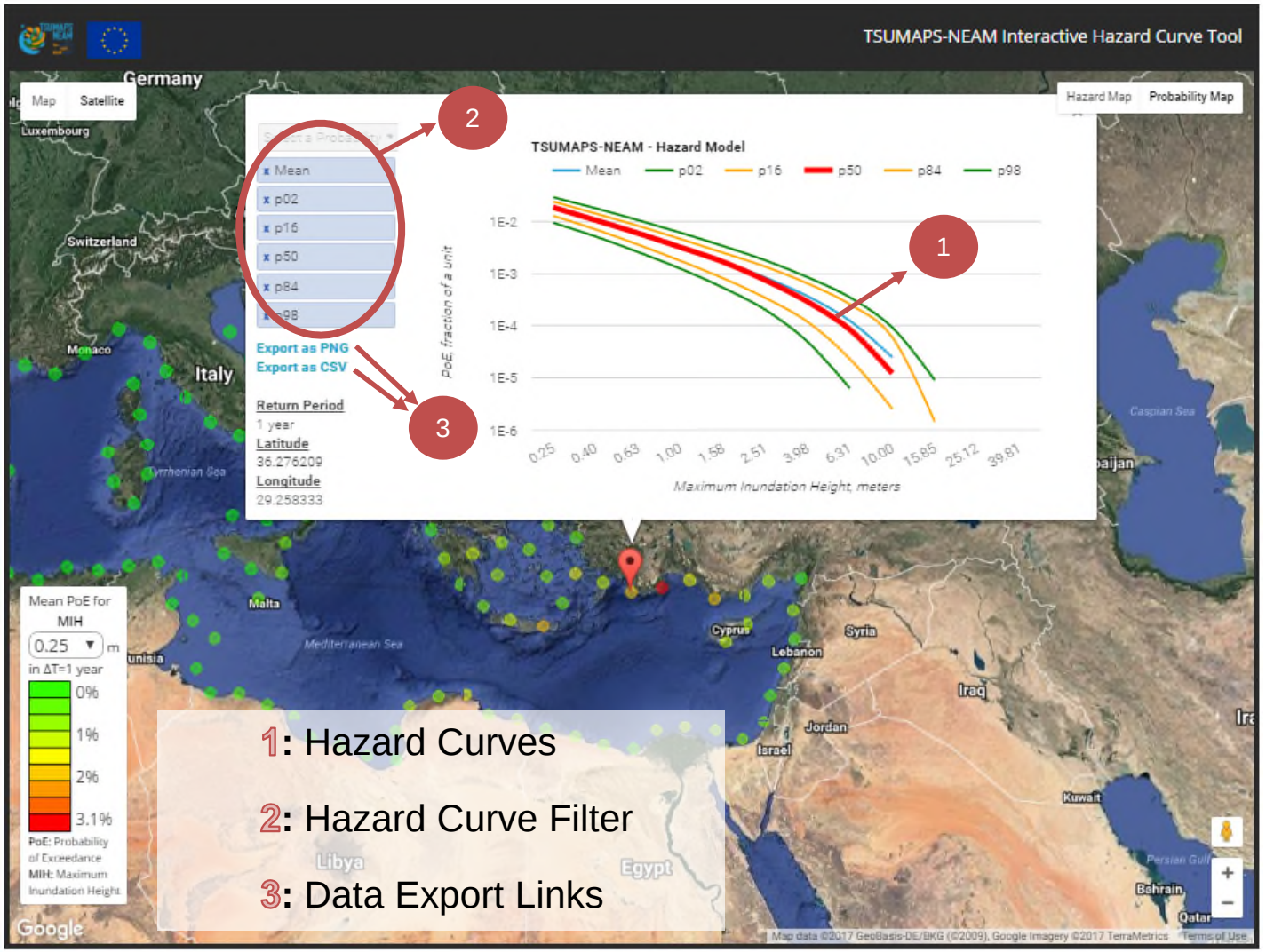
1: Interactive PoI circles

2: Legend with MIH-PoE Switcher

3: Hazard-Probability Map Display Switcher

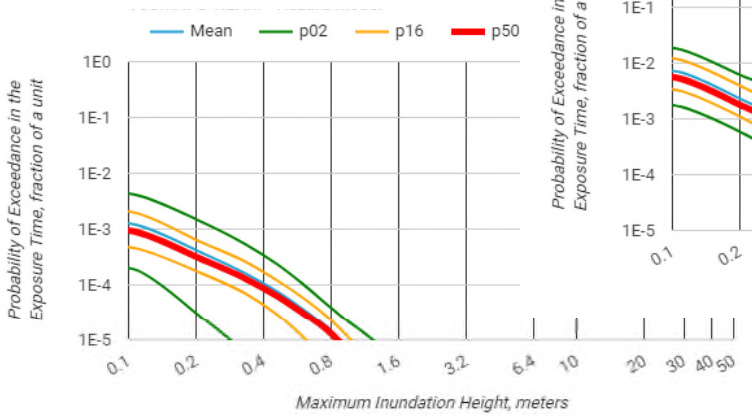
4: Base Map Switcher

Hazard Curve

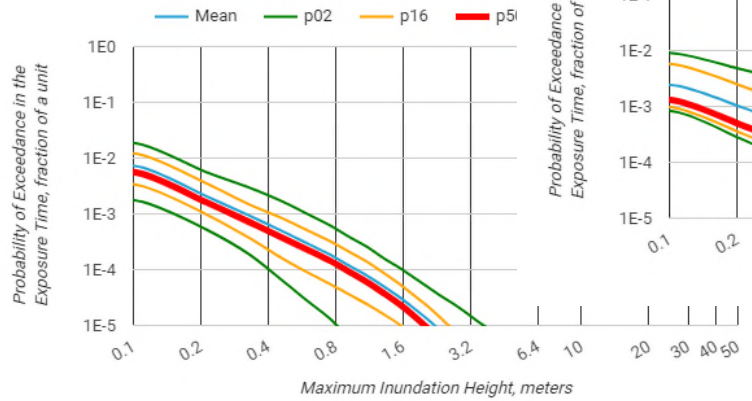


Results: examples of Hazard curves at coastal locations

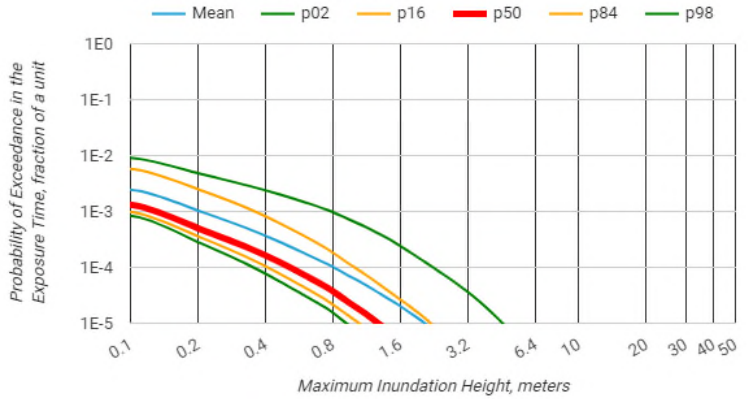
A Coruña



Canarias



Mallorca



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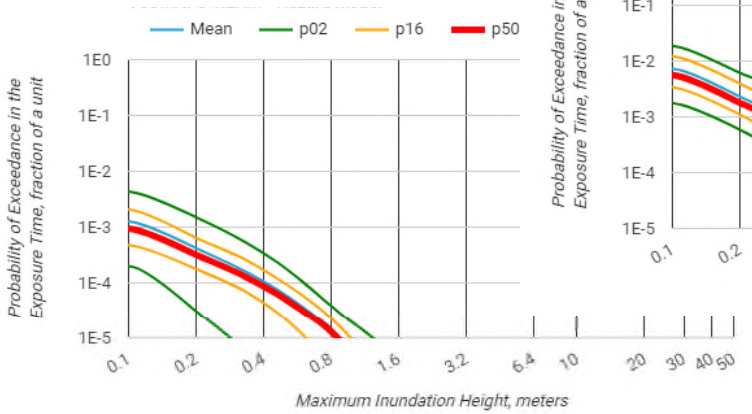
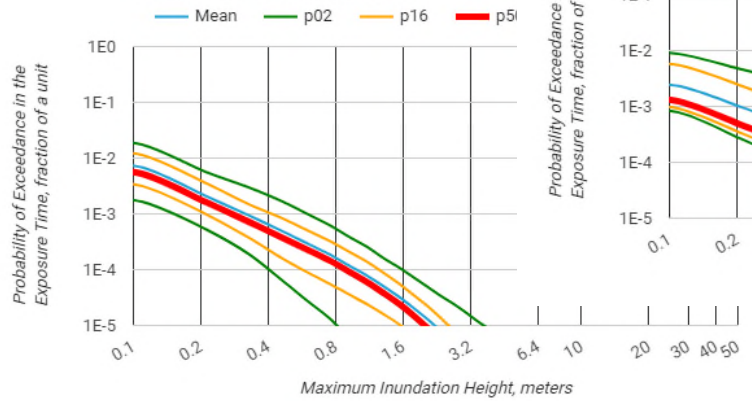
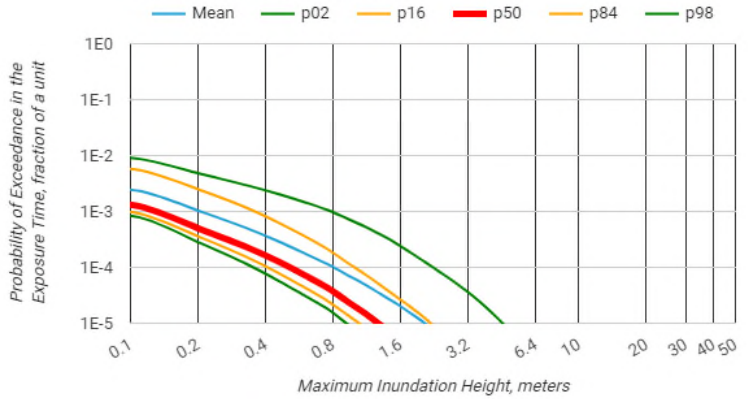


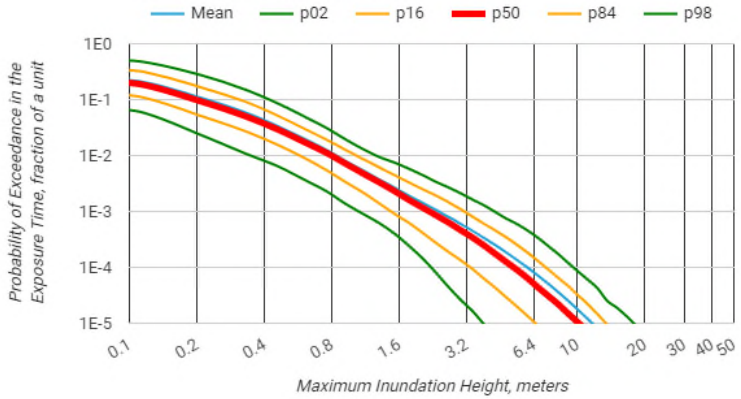
Canarias



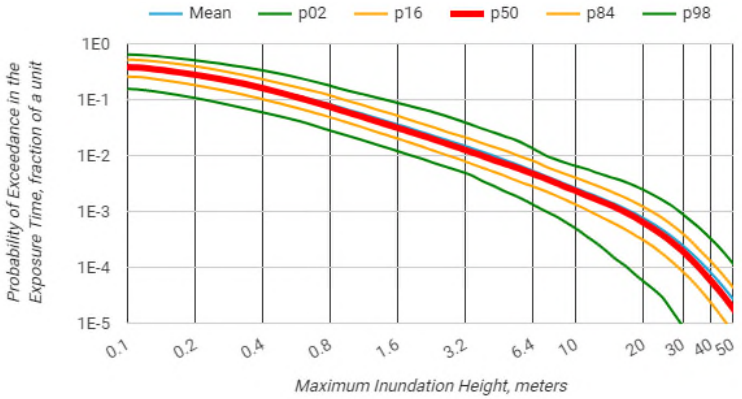
Mallorca



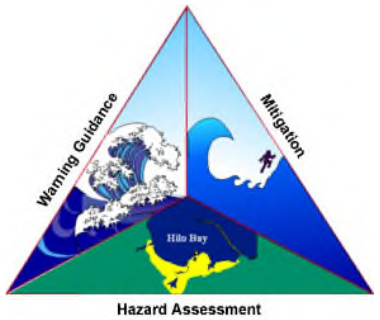
Siracusa, Italy



Alexandria, Egypt



- TSUMAPS-NEAM will provide the NEAMTWS region with the first community-based and homogeneous region-wide probabilistic tsunami hazard assessment
- This effort aims to complement those already being made by IOC/UNESCO ICG/NEAMTWS
- It's a concrete step toward the definition of good practices and guidelines for tsunami hazard
- It's a propaedeutic product for local (more detailed) hazard and risk estimates
- It's an indispensable element for multi-hazard, and multi-risk assessments



Follow the project on our website and social media

http://www.tsumaps-neam.eu

Project Partnership

COORDINATOR

INGV

PARTNERS

NGI

ipma

UNIBA
Centro Universitario
Internacional
de Barcelona

METU

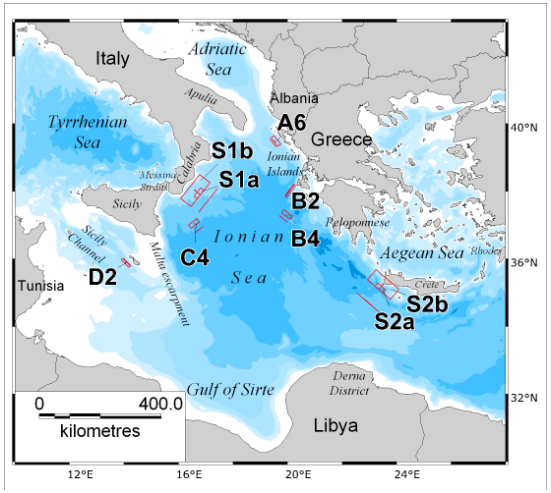
GFZ
Helmholtz Centre
POTSDAM

Institut National de la Meteorologie

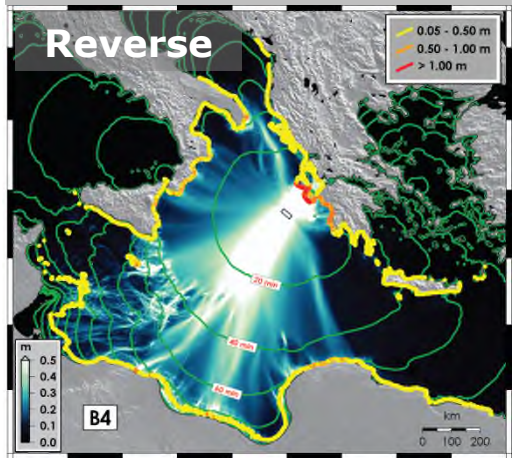
ΕΘΝΙΚΟΝ ΑΣΤΕΡΟΣΚΟΠΕΙΟΝ ΑΘΗΝΩΝ
NATIONAL OBSERVATORY ATHENS

CNRST

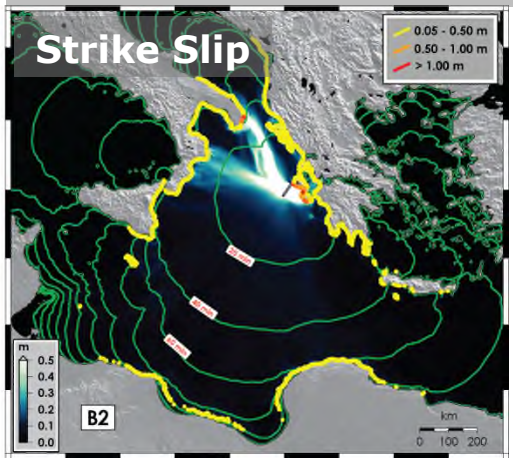
Tsunami scenarios for selected crustal fault ruptures of Mw = 7



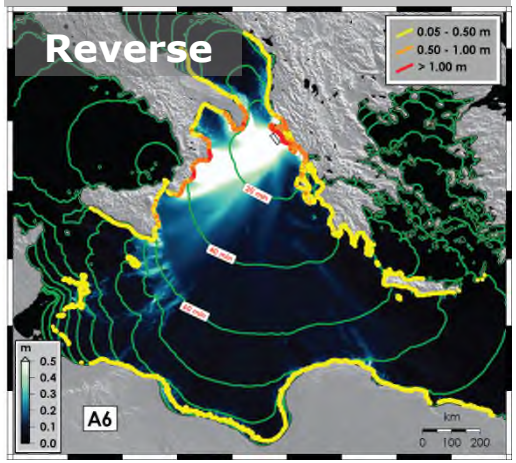
Ionian Island
Transform Fault Zone



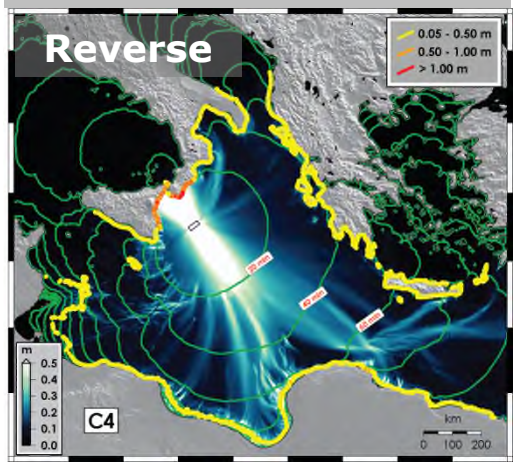
Ionian Island
Transform Fault Zone



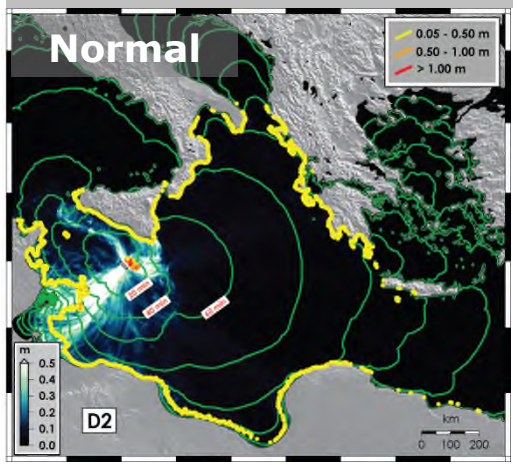
Hellenides
Fold-and-thrust Belt



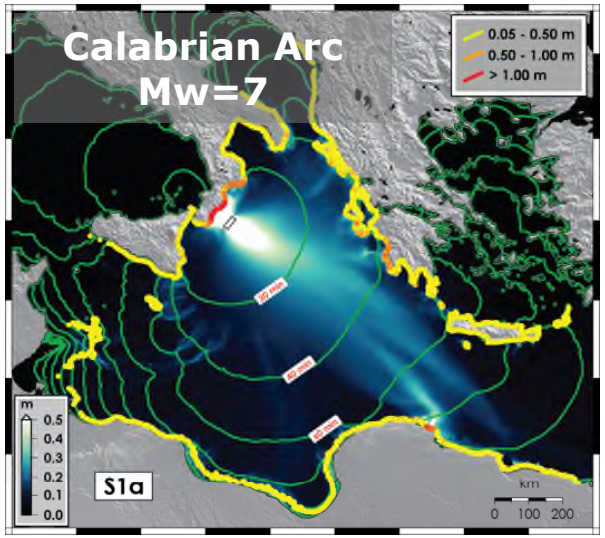
Calabrian
Accretionary Wedge

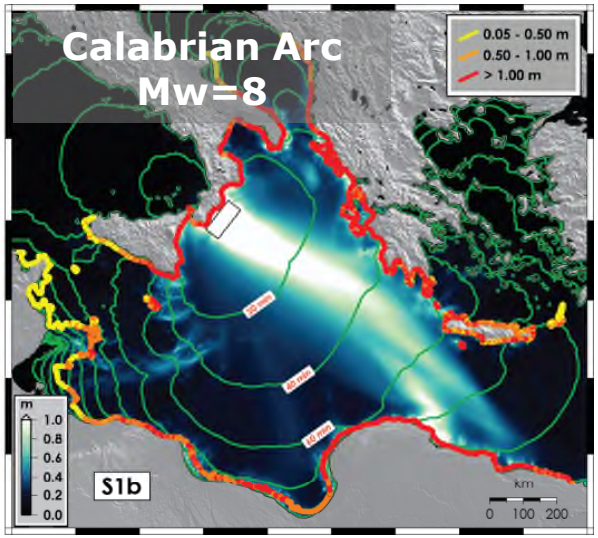


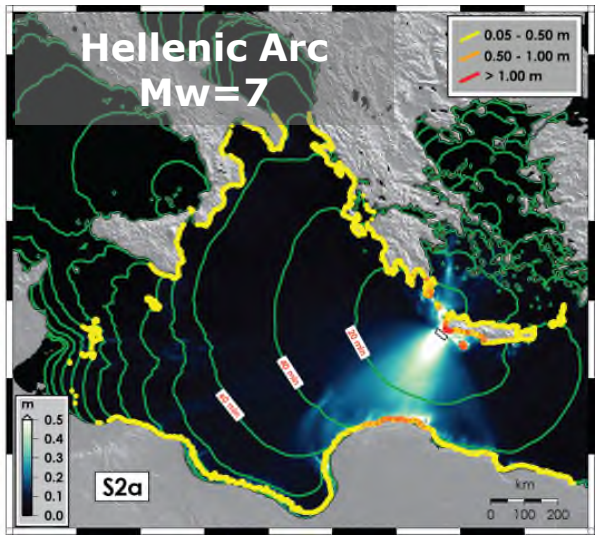
Sicily–Tunisia
Graben

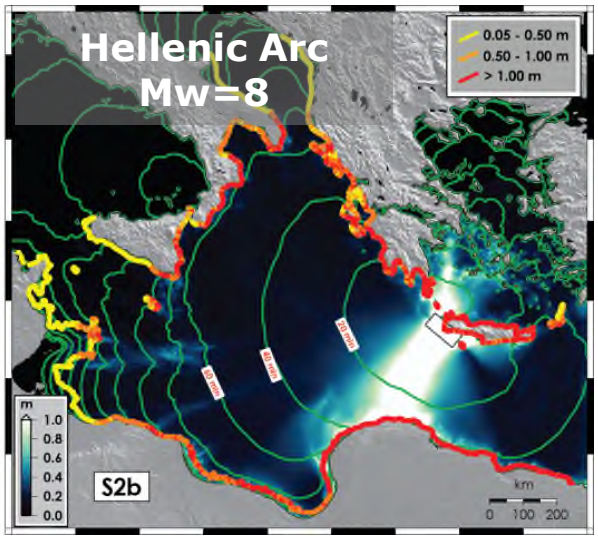


Tsunami scenarios for selected slab interface fault ruptures of Mw = 7 and Mw = 8

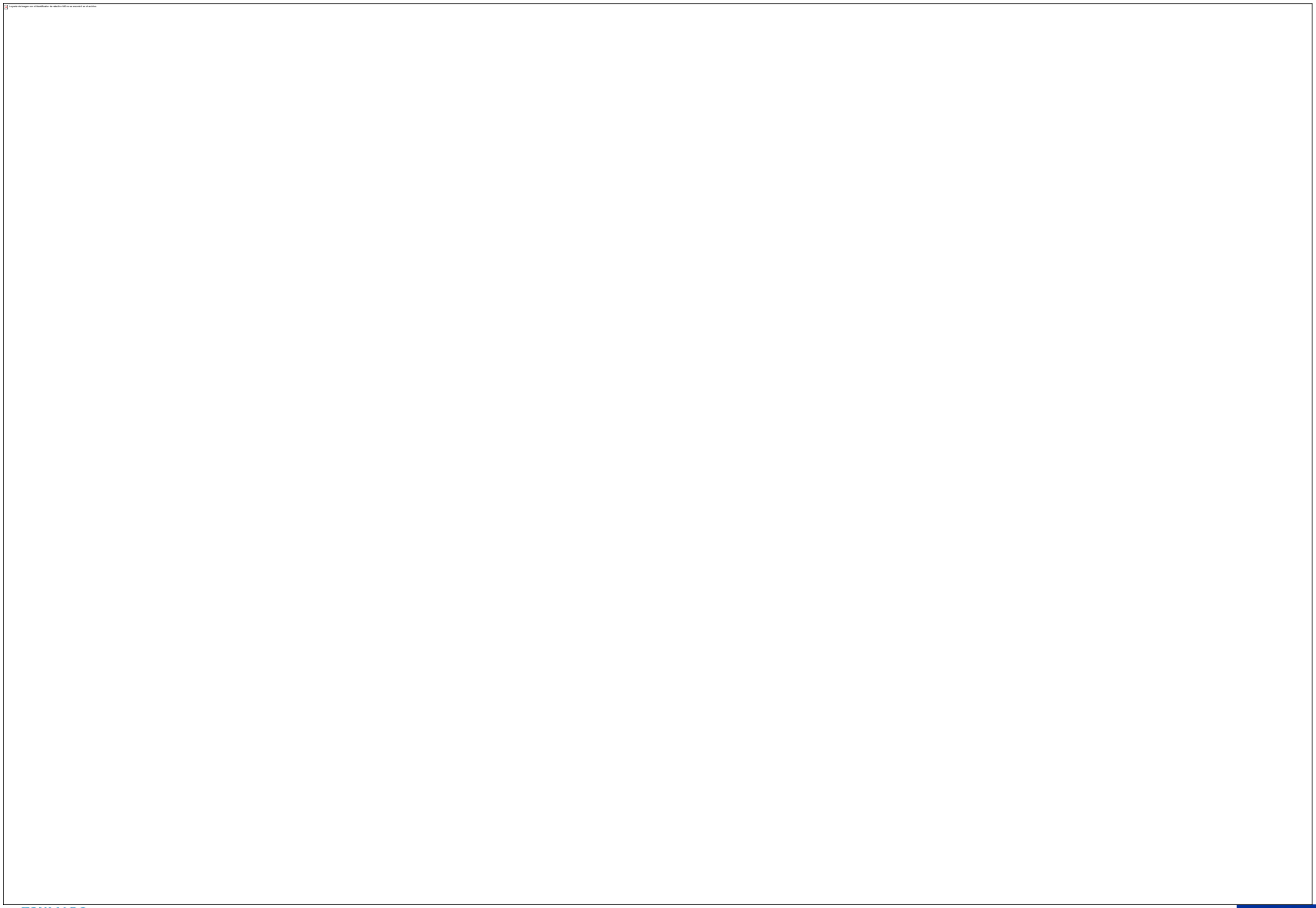








Hazard assessment workflow



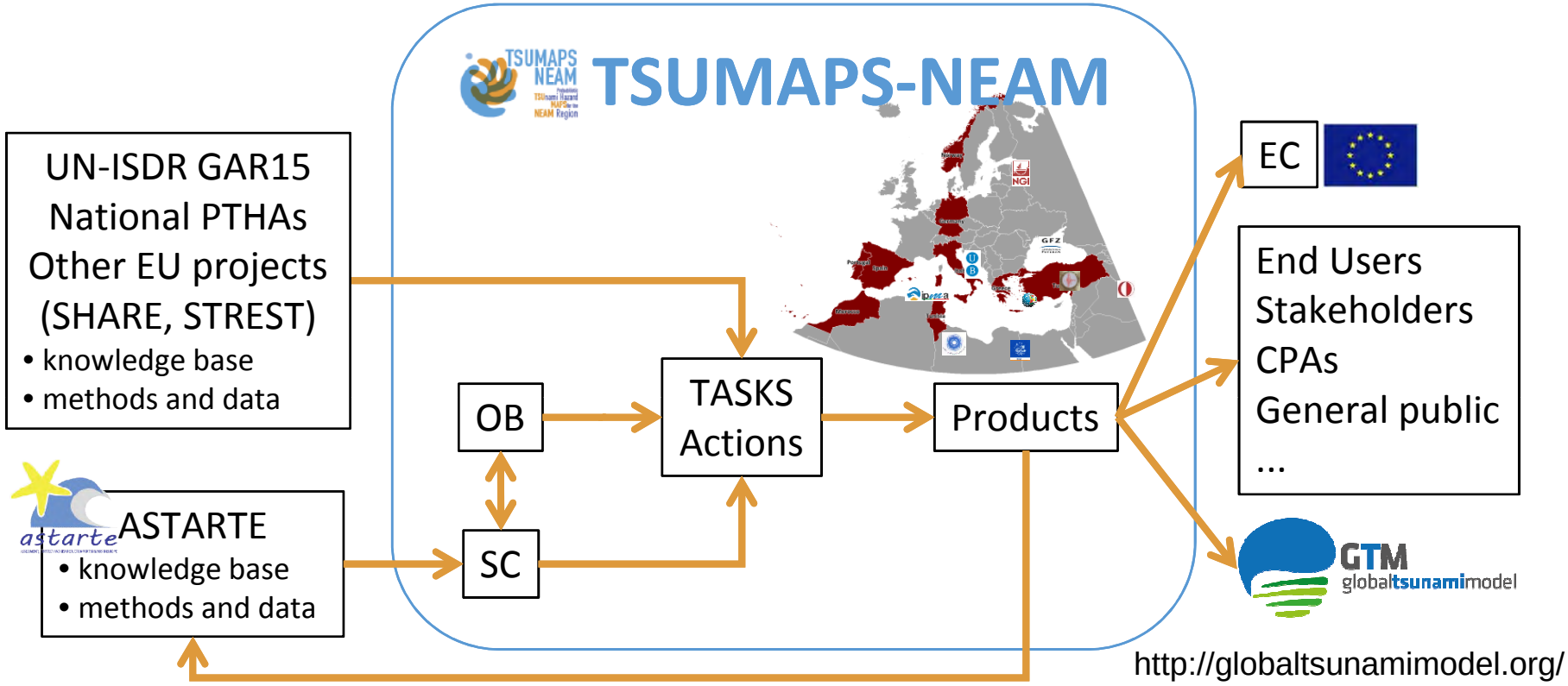
The project at a glance (http://www.tsumaps-neam.eu/)

TSUMAPS-NEAM project objectives:

- produce the first region-wide long-term homogenous PTHA for NEAM;
- trigger a common tsunami risk management strategy in the region.

Task ID	Task Title	Start (Month)	End (Month)	Actions	Deliverables
A	Management and Reporting to the Commission	1	21	A.1 Coordination A.2 Management and Reporting	D1. First Progress Report (M7) D2. Second Progress Report (M14) D3. Final Technical Report (M21)
B	Hazard Assessment	2	21	B.1 Earthquake Model B.2 Tsunami Modelling B.3 Probabilistic Model B.4 Hazard Analysis	D4. Online Tsunami Hazard Database (M14) D5. Tsunami Hazard and Probability Maps (M14)
C	Review and Sanity Check	2	21	C.1 Best Practices C.2 Expert's Review and Sanity Check C.3 Documentation	D6. Experts' Review and Sanity Check (M18) D7. Methods and data Documentation (M18)
D	Publicity	2	21	D.1 Awareness and Education D.2 Capacity Building	D8. Project Website (M4) D9. Awareness and Education Materials (M16) D10. Guidelines and Training Tools (M19) D11. Layman's Report (M21)

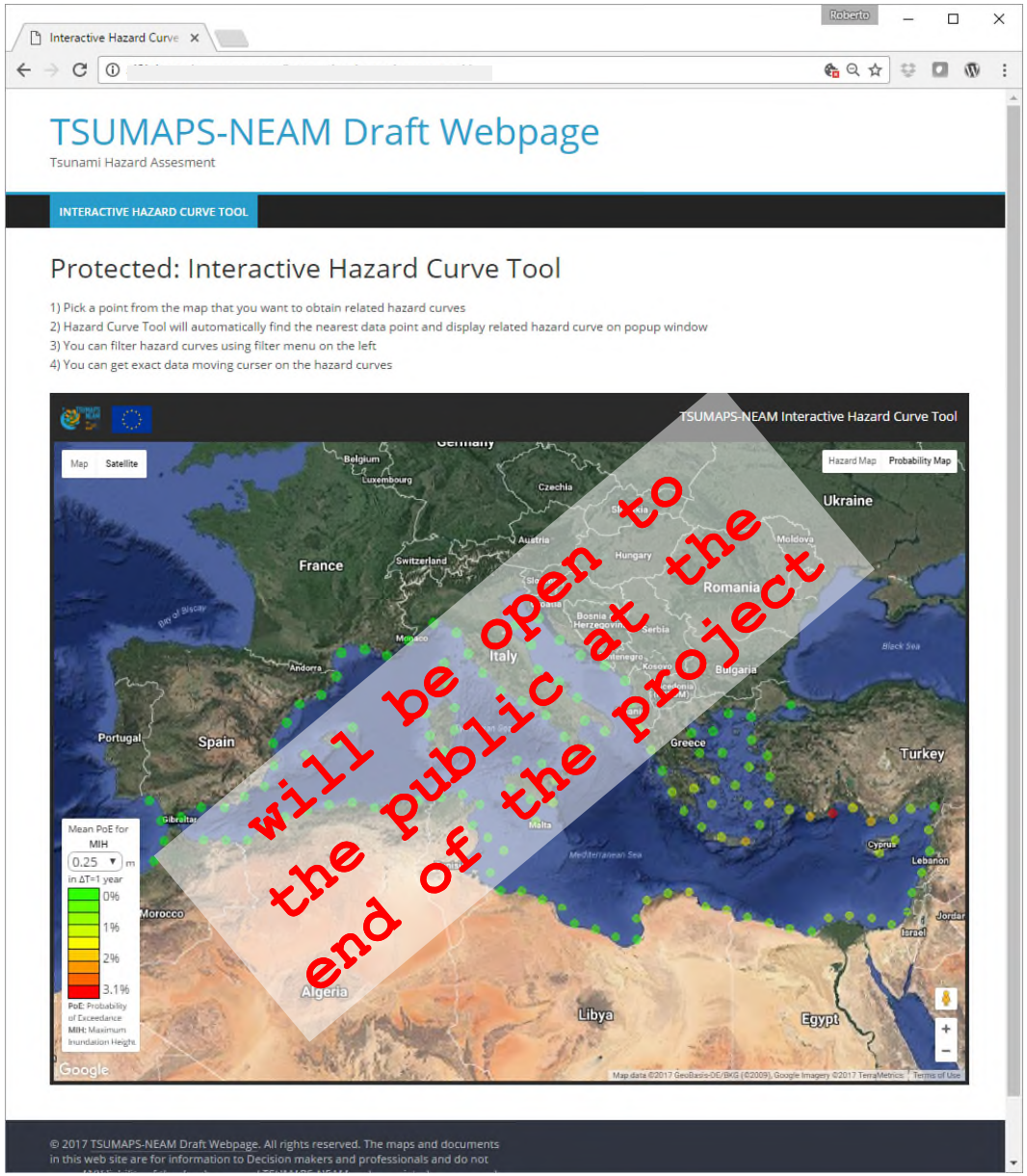
How does the project work?



ASTARTE: *Assessment, STrategy And Risk Reduction for Tsunamis in Europe, EU FP7 project*
SC: *Steering Committee, formed by the TSUMAPS-NEAM Coordinator and all task leaders, plus ASTARTE PMB*
OB: *Observers' Board, formed by end users and advisors*

Interactive Hazard Curve Tool

- online hazard maps for
  - different hazard probabilities
  - different average return periods
- online probability maps for
  - different tsunami amplitudes and MIHs
- online hazard curves for
  - the **mean**, **median**, **2nd**, **16th**, **84th**, and **98th** percentiles



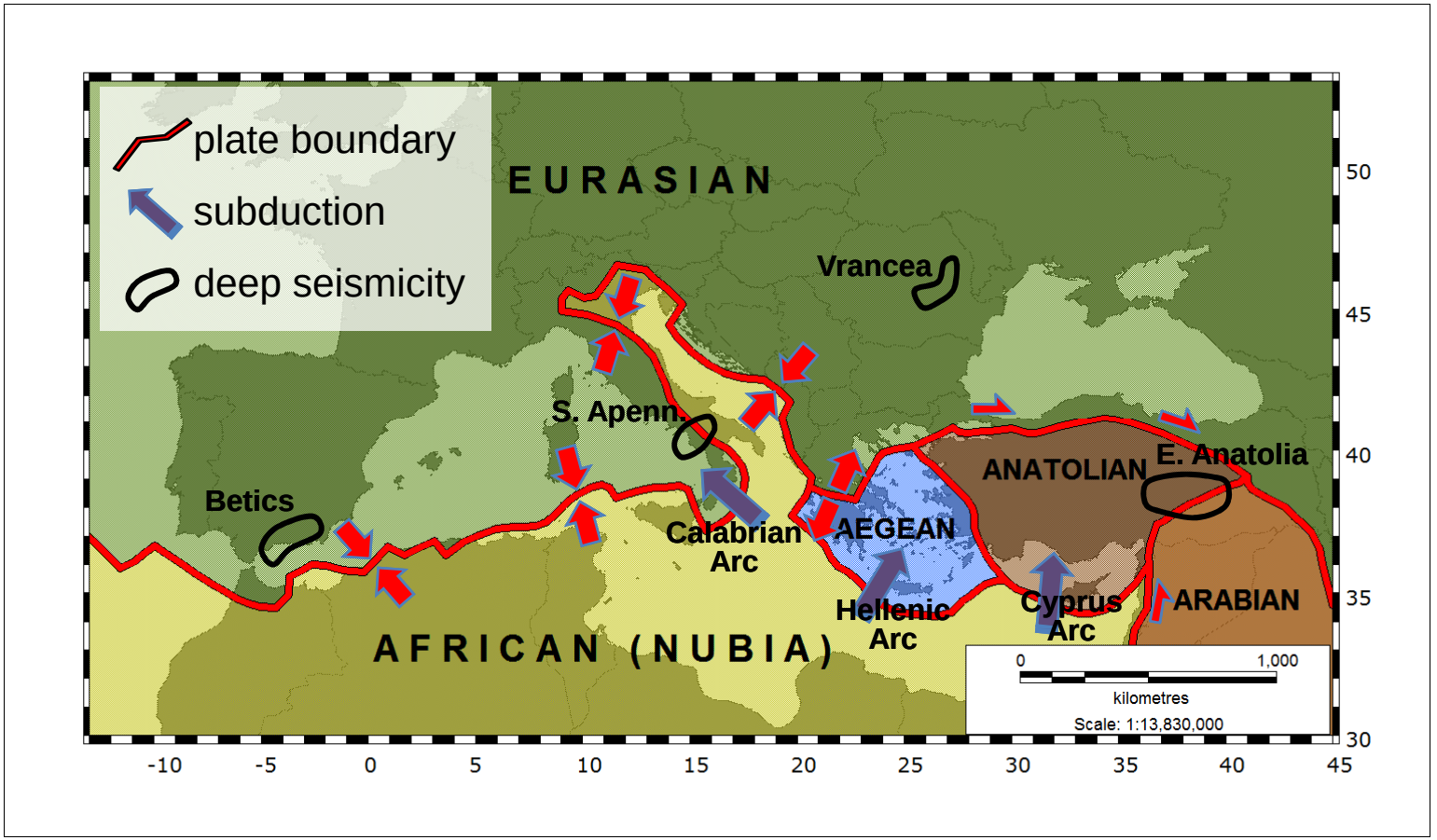
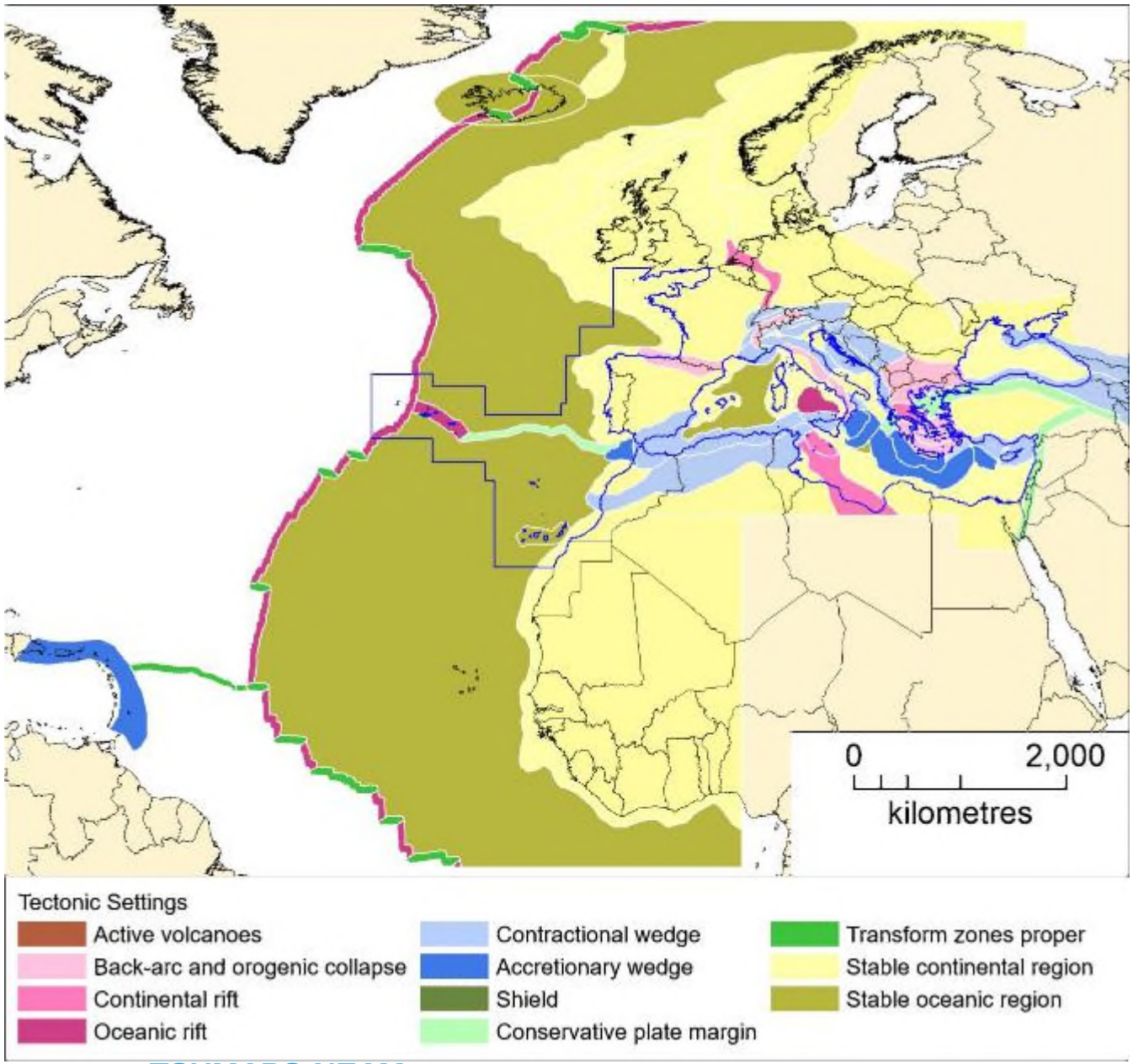
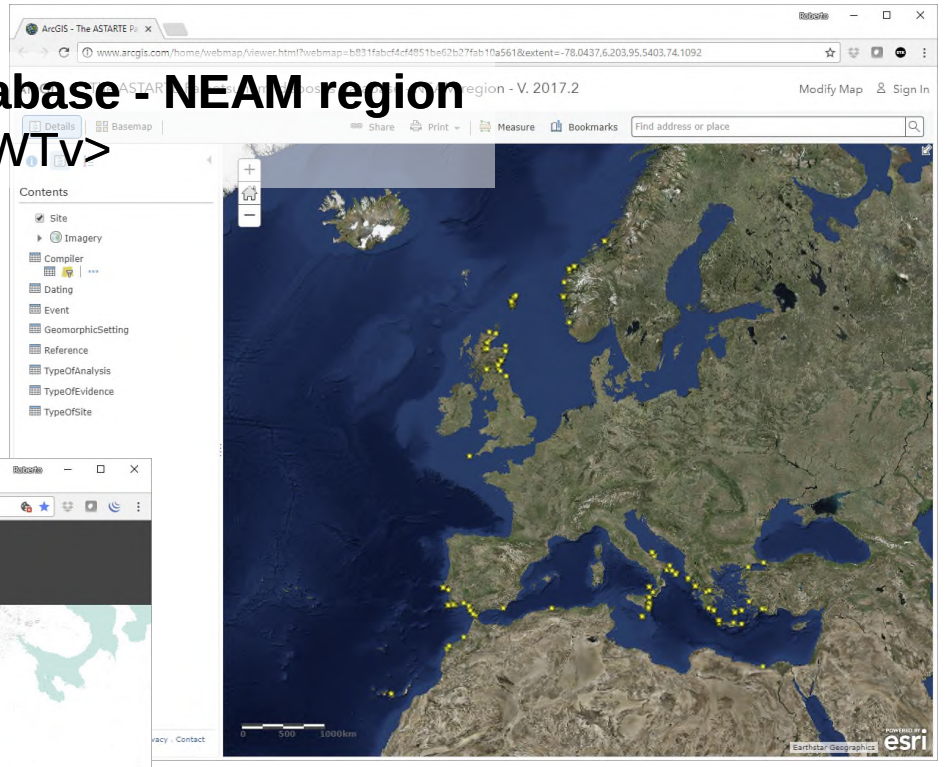


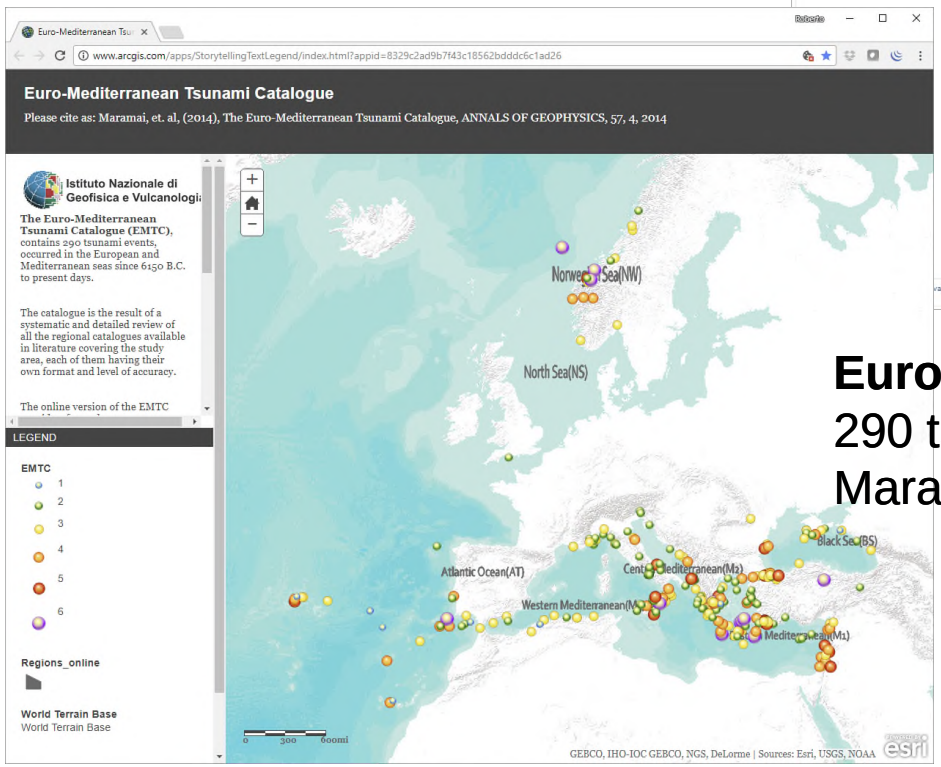
plate boundary
subduction
deep seismicity
EURASIAN
Vrancea
S. Apenn.
Betics
Calabrian Arc
AEGEAN
ANATOLIAN
E. Anatolia
Hellenic Arc
Cyprus Arc
ARABIAN
AFRICAN (NUBIA)
0
1,000
kilometres
Scale: 1:13,830,000
50
45
40
35
30
-10
-5
0
5
10
15
20
25
30
35
40
45

Tectonic regionalization



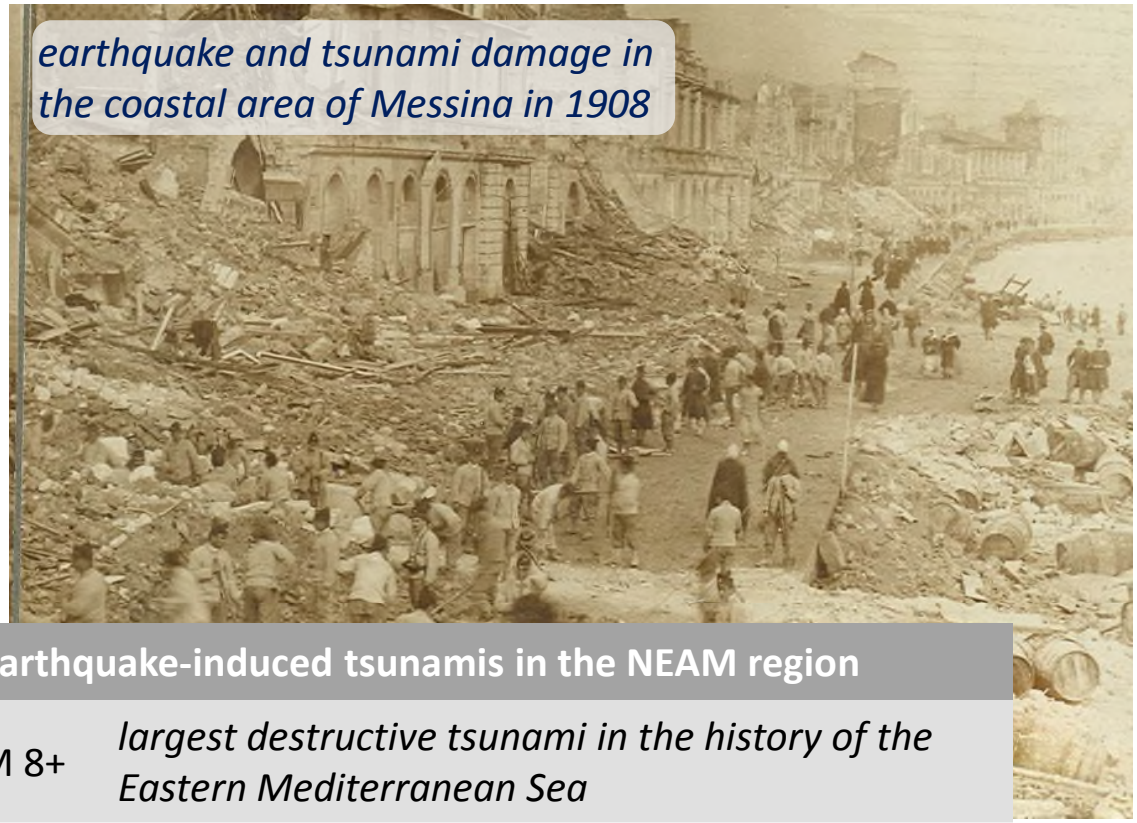
ASTARTE Paleotsunami Deposits database - NEAM region
De Martini et al., 2017 <http://arcg.is/00jWTv>





Euro-Mediterranean Tsunami Catalogue
290 tsunamis since 6150 BCE
Maramai et al., 2014, AoG

Tsunamis are low-frequency high-consequence events. Probabilistic assessment of tsunami hazard is a strategic tool for tsunami and multi-risk mitigation.

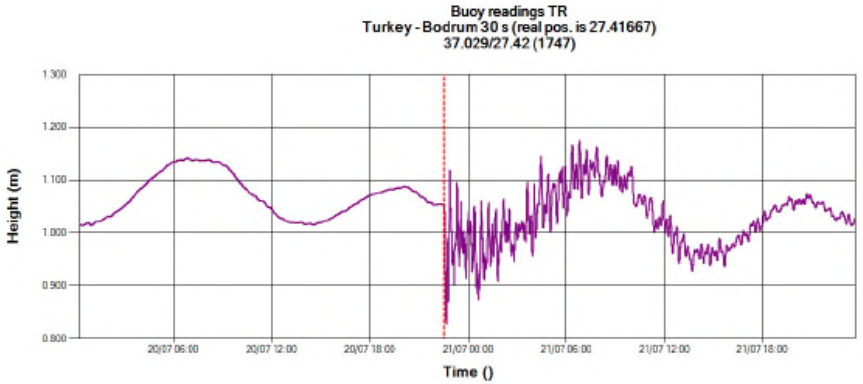


earthquake and tsunami damage in the coastal area of Messina in 1908

Selection of dreadful historical earthquake-induced tsunamis in the NEAM region			
Jul 21, 365 AD	Crete, Greece	M 8+	*largest destructive tsunami in the history of the Eastern Mediterranean Sea*
Nov 1, 1755	Lisbon, Portugal	M 8+	*large destructive tsunami in history of the Eastern Atlantic Sea*
Dec 28, 1908	Messina, Italy	M 7.1	*deadliest tsunami of the instrumental era in the central Mediterranean Sea*
May 21, 2003	Boumerdès, Algeria	M 6.8	*first tsunami of the new millennium in the Western Mediterranean Sea*

July 20, 2017 (22:31 UTC) Bodrum/Kos earthquake (Mw 6.6) and tsunami

Wake-up call?



From Yalciner et al., 2017, Post-tsunami field survey Report

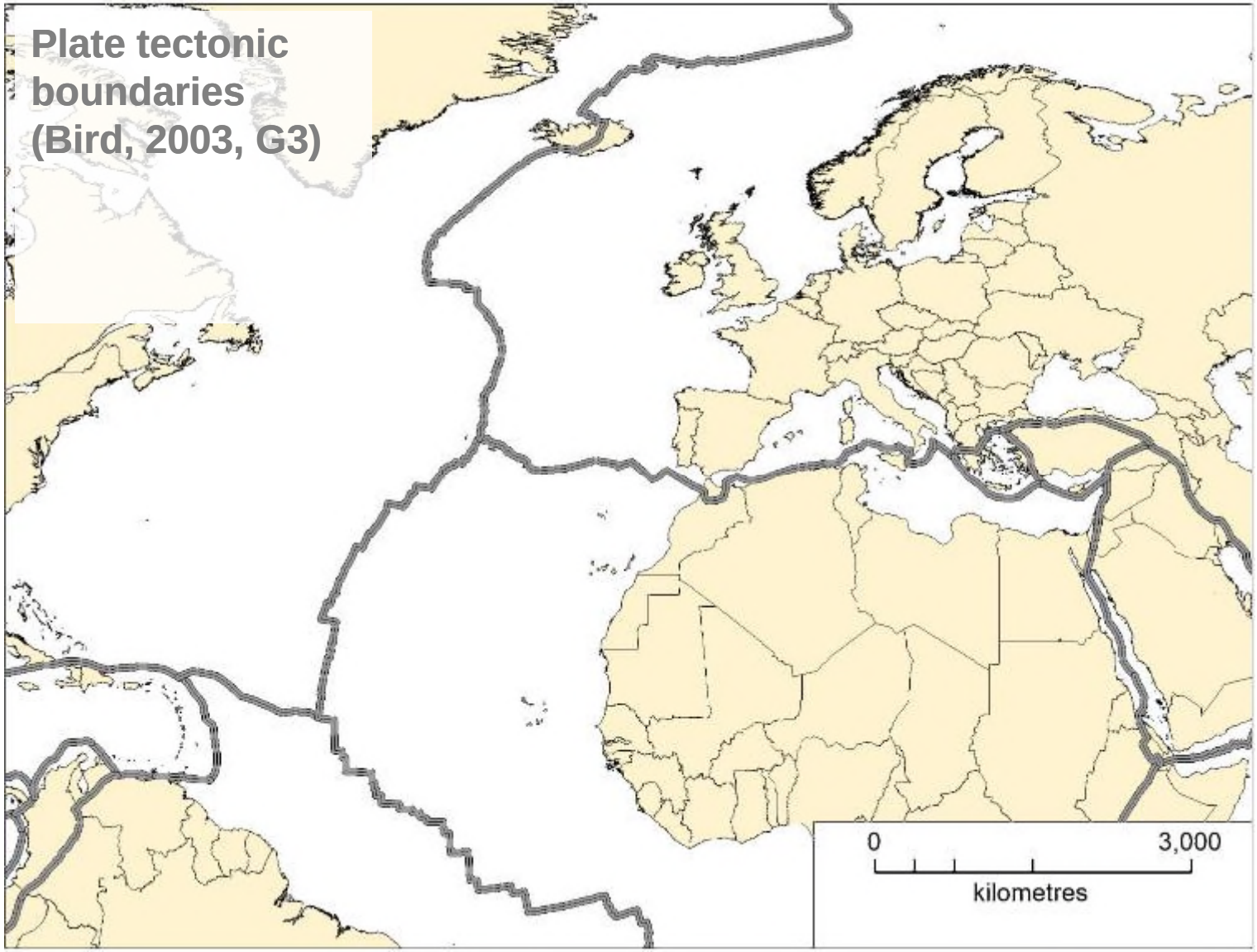


Plate tectonic boundaries (Bird, 2003, G3)
0
3,000
kilometres

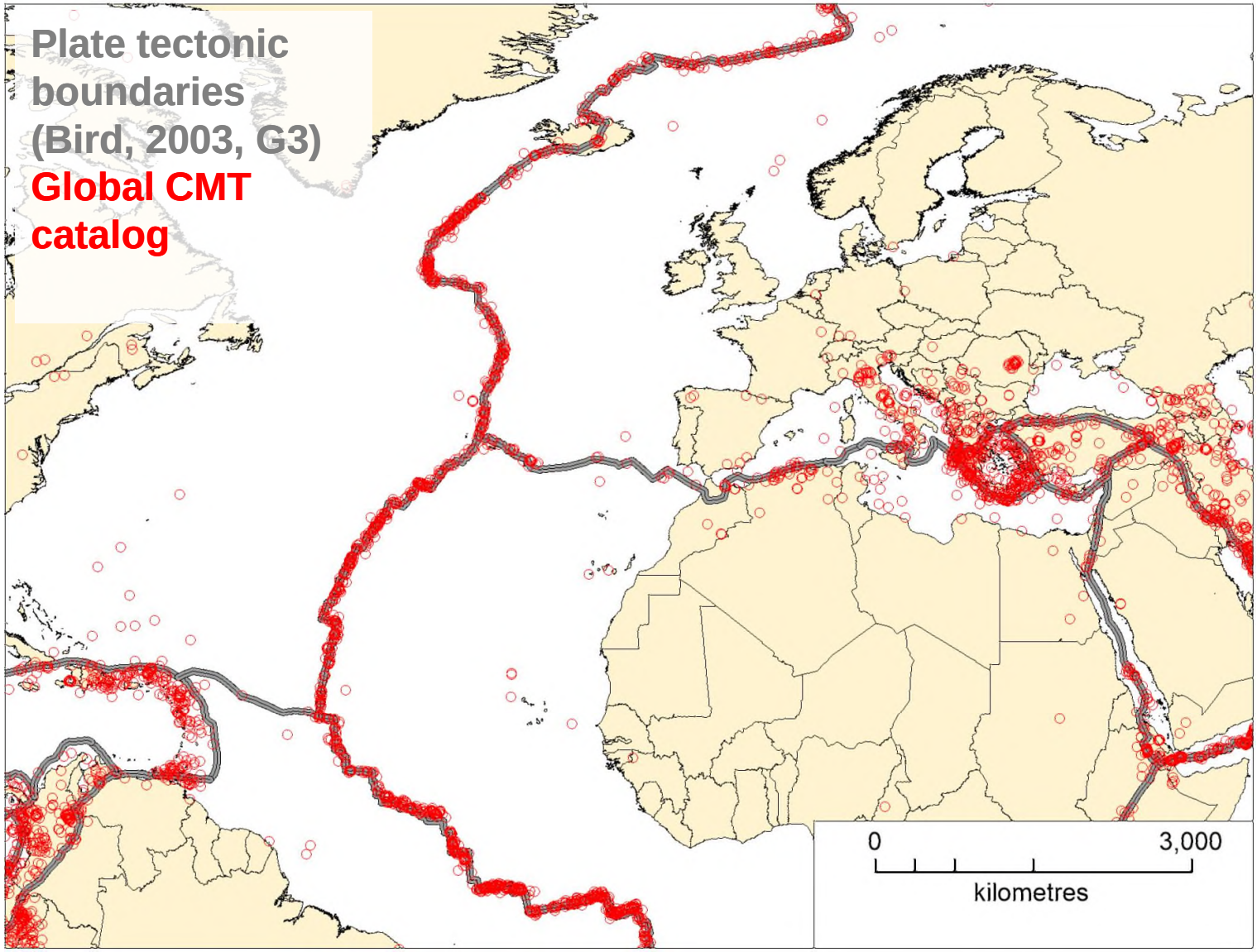


Plate tectonic boundaries (Bird, 2003, G3)
Global CMT catalog
0
3,000
kilometres

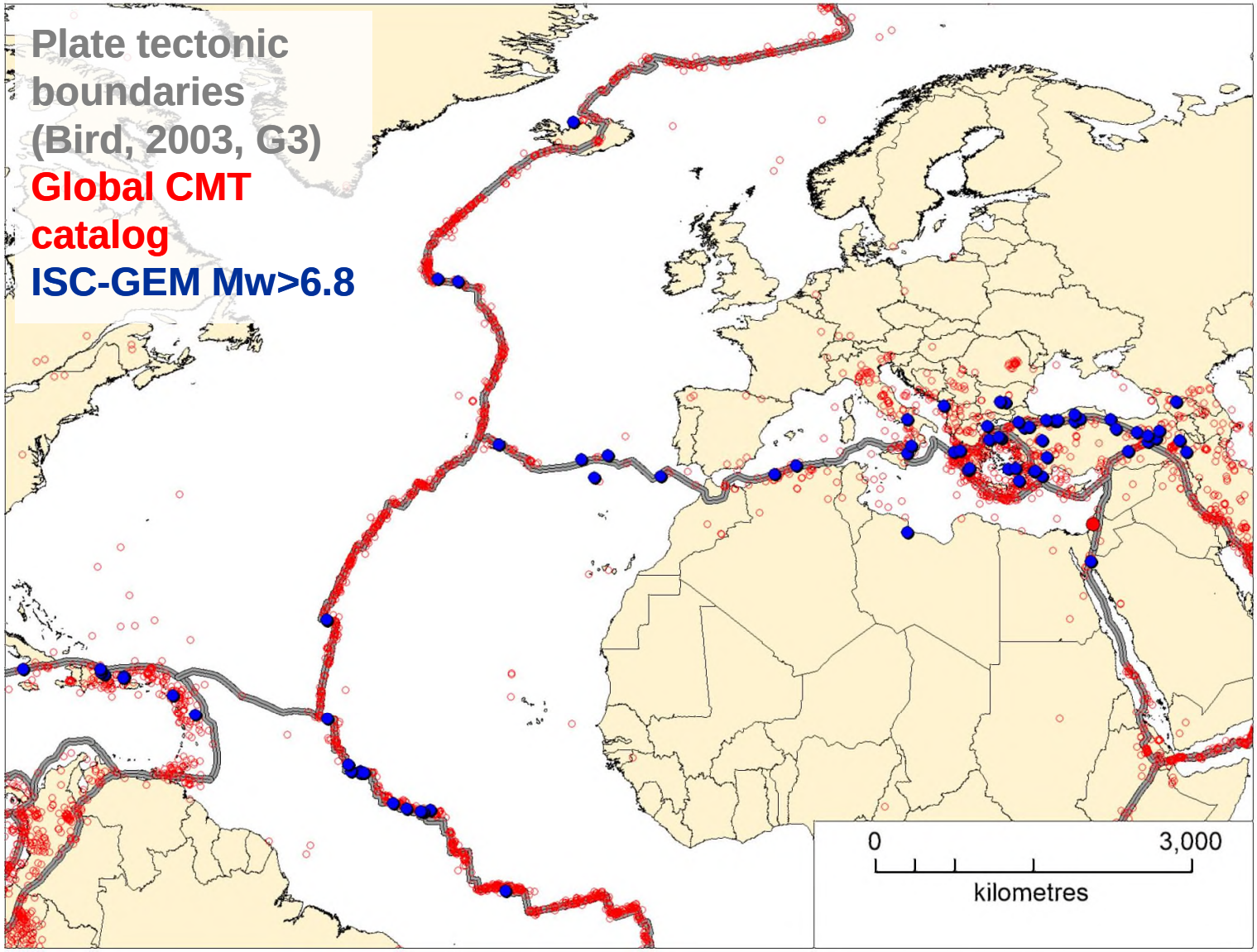


Plate tectonic boundaries (Bird, 2003, G3)
Global CMT catalog
ISC-GEM Mw>6.8
0
3,000
kilometres