G T M

stands for:

Global **T**sunami **M**odel

What is GTM?

GTM is a network of organizations and individuals working together toward a science-based understanding of tsunami hazard and risk as well as development of standards and tools to quantify them.

G T M

stands for:

Global **T**sunami **M**odel

Why GTM?

Both ocean-wide and local tsunamis pose a substantial portion of global hazard and risk to world population and economies. GTM was born in response to the community need for standardization of tsunami hazard and risk assessment.

G T M

stands for:

Global **T**sunami **M**odel

What are GTM vision and goals?

The GTM overall vision and goals are to collaboratively achieve a thorough understanding of tsunami hazard and risk, together with the processes that drive them. The GTM-Network aims to:

- assess and provide community-based standards, good practices and guidelines for Probabilistic Tsunami Hazard and Risk Analysis (PTHA and PTRA)
- provide a portfolio of PTHA and PTRA modeling tools
- develop regional and global reference probabilistic tsunami hazard and risk maps, as well as standardized processes for local hazard and risk analyses
- establish reference pools of experts for completing and reviewing tsunami hazard and risk assessments from stakeholders
- interaction with stakeholders to ensure relevance and proper dissemination of results and uncertainty communication to non-scientists

GTM will contribute to the Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030

SFDRR Four priorities:

- **Priority 1. Understanding disaster risk**
- Priority 2. Strengthening disaster risk governance to manage disaster risk
- Priority 3. Investing in disaster risk reduction for resilience
- Priority 4. Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction

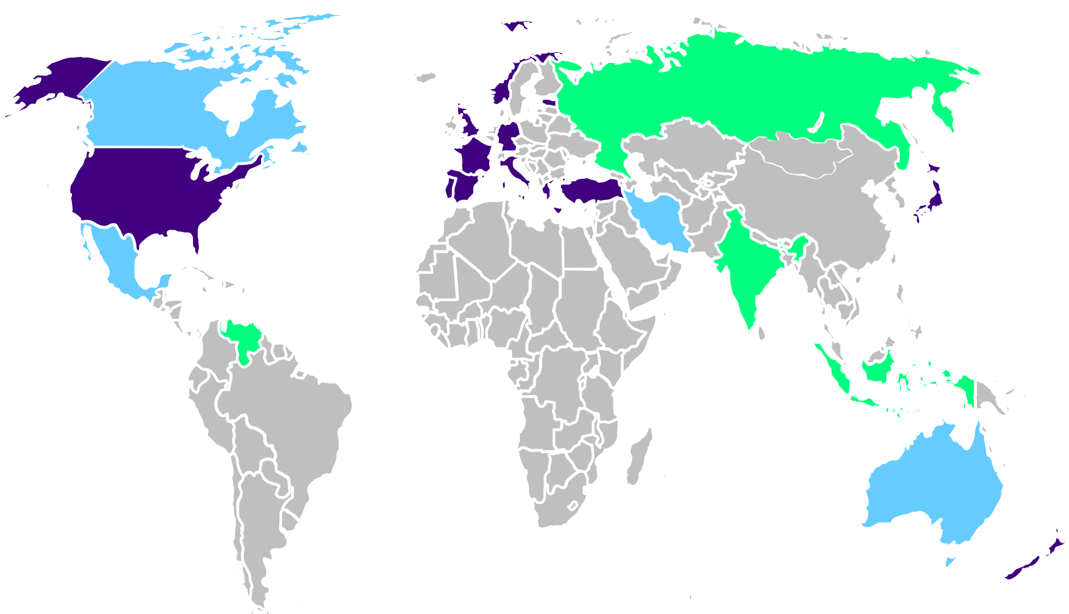
SFDRR Seven Global Targets in brief

- Substantially reduce global disaster **mortality**
- Substantially reduce the **number of affected people** globally
- Reduce direct **disaster economic loss** in relation to global gross domestic product (GDP)
- Substantially reduce disaster **damage to critical infrastructure and disruption of basic services**, among them health and educational facilities, including through developing their resilience
- Substantially increase the number of countries with national and local disaster risk reduction strategies
- Substantially enhance **international cooperation to developing countries**
- Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to the people

Current GTM structure

- ✓ proposed to the tsunami community at IUGG June 2015, discussed among partners in several meetings since (AGU, EGU…)
- ✓ **Loose structure committing partners** to the GTM through signing of Letter of Interest (LoI's)
- ✓ 25 partners have signed LoI's, more than 30 partners interested (involved in meetings, etc.)
- ✓ **NGI** and **INGV** receive LoI's on behalf of GTM and perform majority of secretary work

*Coordinated by **Finn Lovholt** (INGV) and **Stefano Lorito** (INGV)*



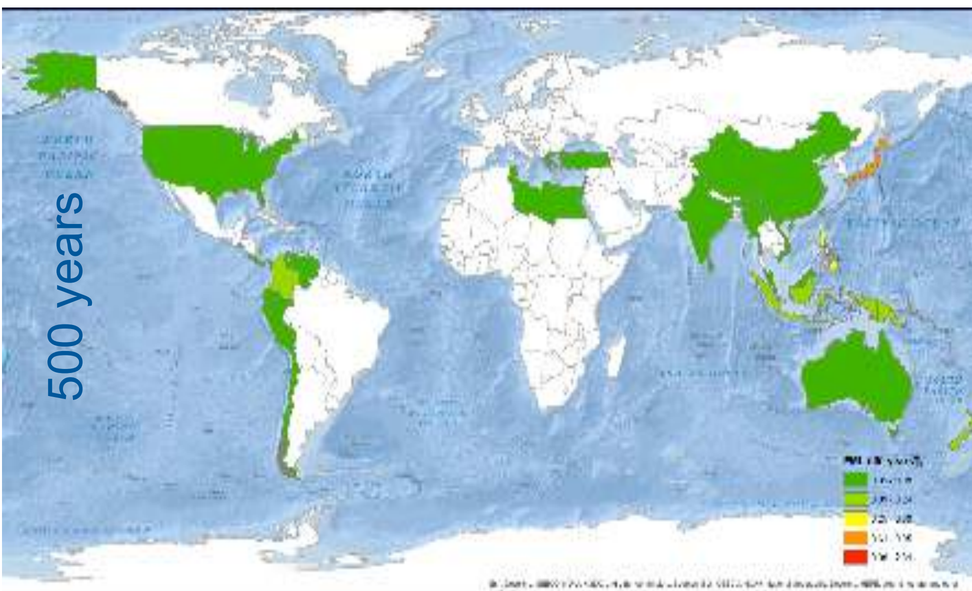
Example #1 of GTM-Projects – Global Tsunami Risk Maps

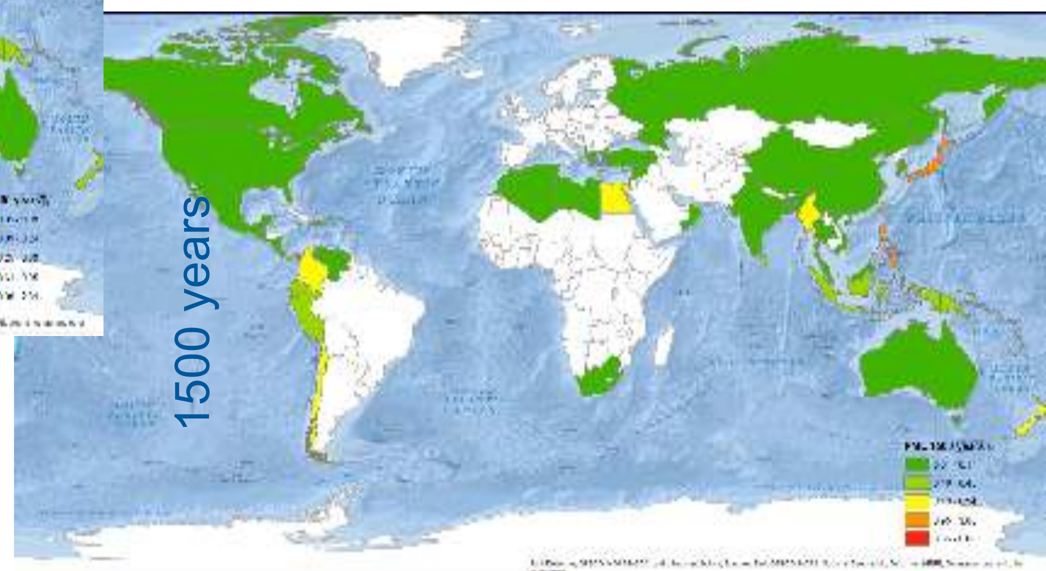
Present maps from GAR15 – probable maximum loss relative to total exposed value

GAR

Global Assessment Report
on Disaster Risk Reduction

2015





Davies et al. (2017)

Example #2 of GTM-Projects – Regional PTHA

TSUMAPS NEAM

Probabilistic TSUnami Hazard MAPS for the NEAM Region

Funded by European Union Humanitarian Aid & Civil Protection

End Users and Advisers

PROTEZIONE CIVILE

BOĞAZIÇI UNIVERSITY

USGS

EPOS

EUROPEAN COMMISSION

Motivation / Goals

- Produce first region-wide long-term homogeneous S-PTHA (Seismic Probabilistic Tsunami Hazard Assessment) for North-East Atlantic and Mediterranean (NEAM)
- Full uncertainty treatment
- Community-based consensus model
- Employ SSHAC guidelines for trimming and weighting of alternative models
- Trigger a common tsunami risk management strategy in the region

Geographical Scope

TSUMAPS NEAM
Probabilistic TSUnami Hazard MAPS for the NEAM Region

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

Hazard assessment workflow

STEP 1 — **Probabilistic earthquake model**

Goals:
- *definition of the parameters of all the possible representative seismic sources that may generate tsunamigenic earthquakes in the future;*
- *quantification of their long-term frequency (mean annual rates).*

This analysis is performed with an Event Tree that decomposes the problem into a chain of discrete conditional probabilities for aleatory variables describing the earthquakes.

Levels:

Regionalization & Seismic DBs	Magnitude-Frequency Distribution (MFD) for predominant seismicity (PS) and background seismicity (BS)	Variability of earthquakes for BS in each region and for each magnitude of the MFD	Variability of earthquakes for PS on each main fault and for each magnitude of the MFD

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

Goals:
- *simulation of the sea floor displacement;*
- *simulation of the tsunami generation and propagation from the source to the target area, up to a given bathymetric depth.*

The output of this step are tsunami waveforms, modeled on a chosen isobath along the coasts of interest at chosen points of interest in front of them.

Levels:

Crustal model (elastic parameters, friction), topo-bathymetric datasets, and digital elevation models	Coseismic displacement	Tsunami generation model	Tsunami propagation model (in deep water)

STEP 3 — **Shoaling and inundation**

Goals:
- *simulation of the last phases of the tsunami impact;*
- *stochastic simulation of the associated uncertainty (including uncertainty deriving both from simplified source modelling and simplified tsunami modelling);*
- *combination of the tsunami with the tides (only for the Atlantic).*

The output of this step are the time histories or the maxima of the chosen hazard metrics (e.g. runup, inundation distance, currents), and their distributions at the chosen points of interest along the coast or inland.

Levels:

Topo-bathymetric datasets and digital elevation models	Amplification and inundation model	Tidal stage model	Uncertainty modeling for hazard metrics (including stochastic modeling of non-modeled effects from STEPS 1-3, and tides)

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

Goals:
- *quantification of the hazard curves at the target sites;*
- *disaggregation analyses.*

Each considered alternative produces a hazard curve. Weights assigned to alternatives are critical. The ensemble of the hazard curves is analyzed for uncertainty estimation. Statistics (quantiles) of the ensemble characterize results and their uncertainty. Hazard curves are used to produce hazard and probability maps.

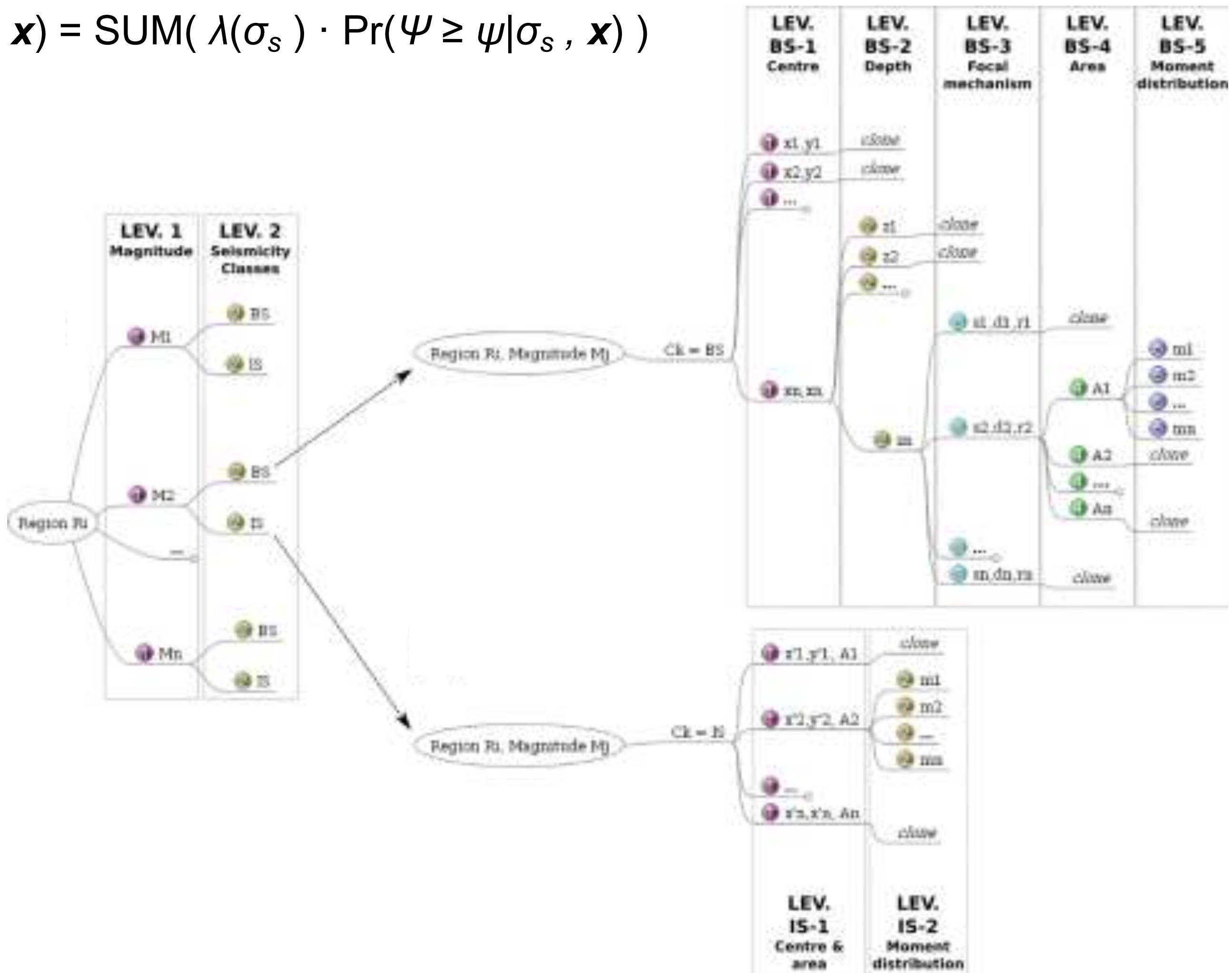
Levels:

Elicitation of experts, historical tsunami DB, paleotsunami DB	Combination of STEPS from 1-3	Quantification of uncertainty	Comparison/test with tsunami records (in few test sites)

Probability integration and Event Tree

$$\Pr(\boldsymbol{\Psi} \geq \psi, \mathbf{x}, T) = 1 - \exp(-\lambda^{Tot}(\Psi \geq \psi, \mathbf{x}) \cdot T)$$

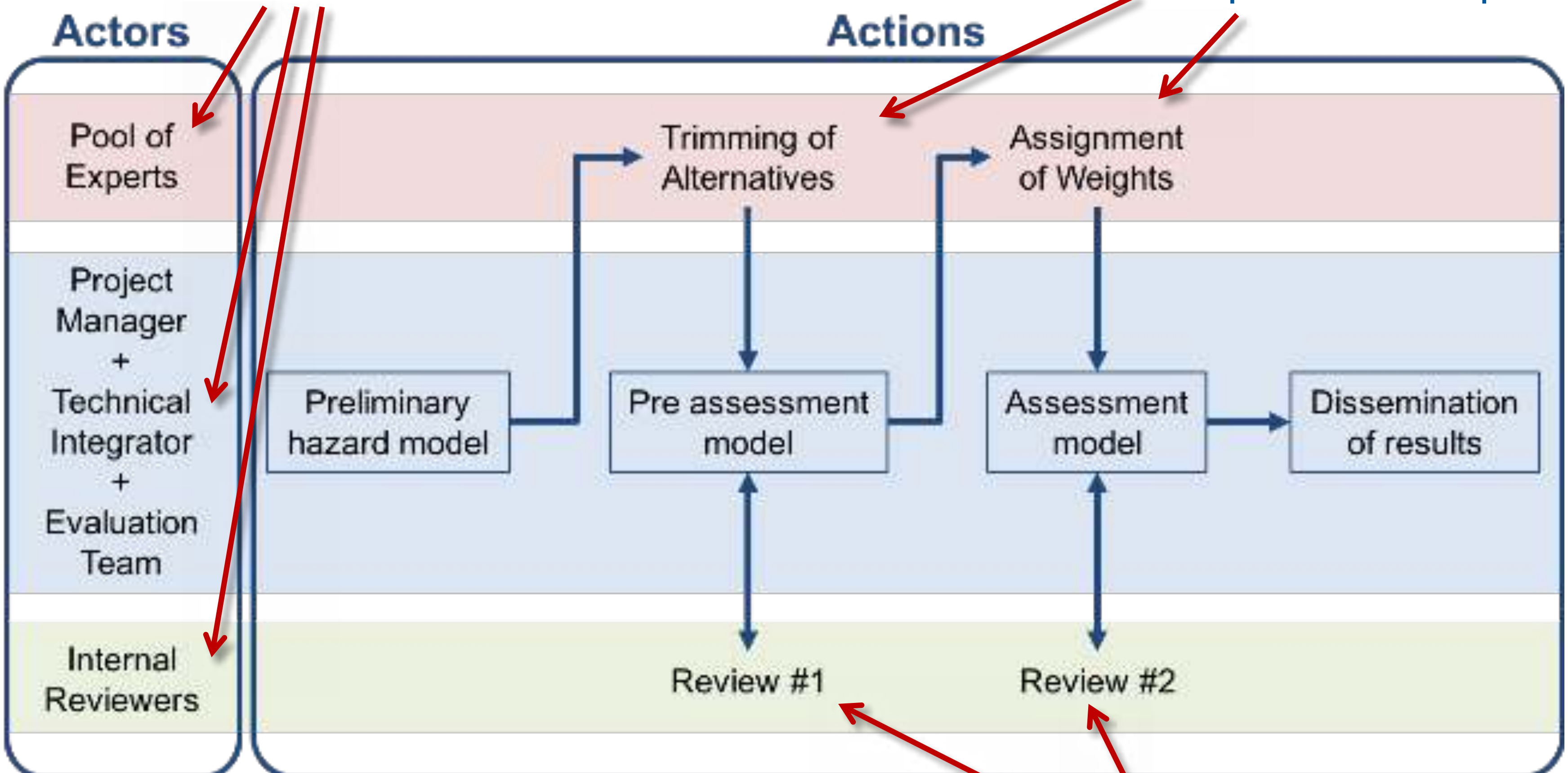
$$\lambda^{Tot}(\Psi \geq \psi, \mathbf{x}) = \mathrm{SUM}(\lambda(\sigma_s) \cdot \Pr(\Psi \geq \psi | \sigma_s, \mathbf{x}))$$



Multiple-Expert Protocol to Manage Epistemic Uncertainty *(after SSHAC guidelines)*

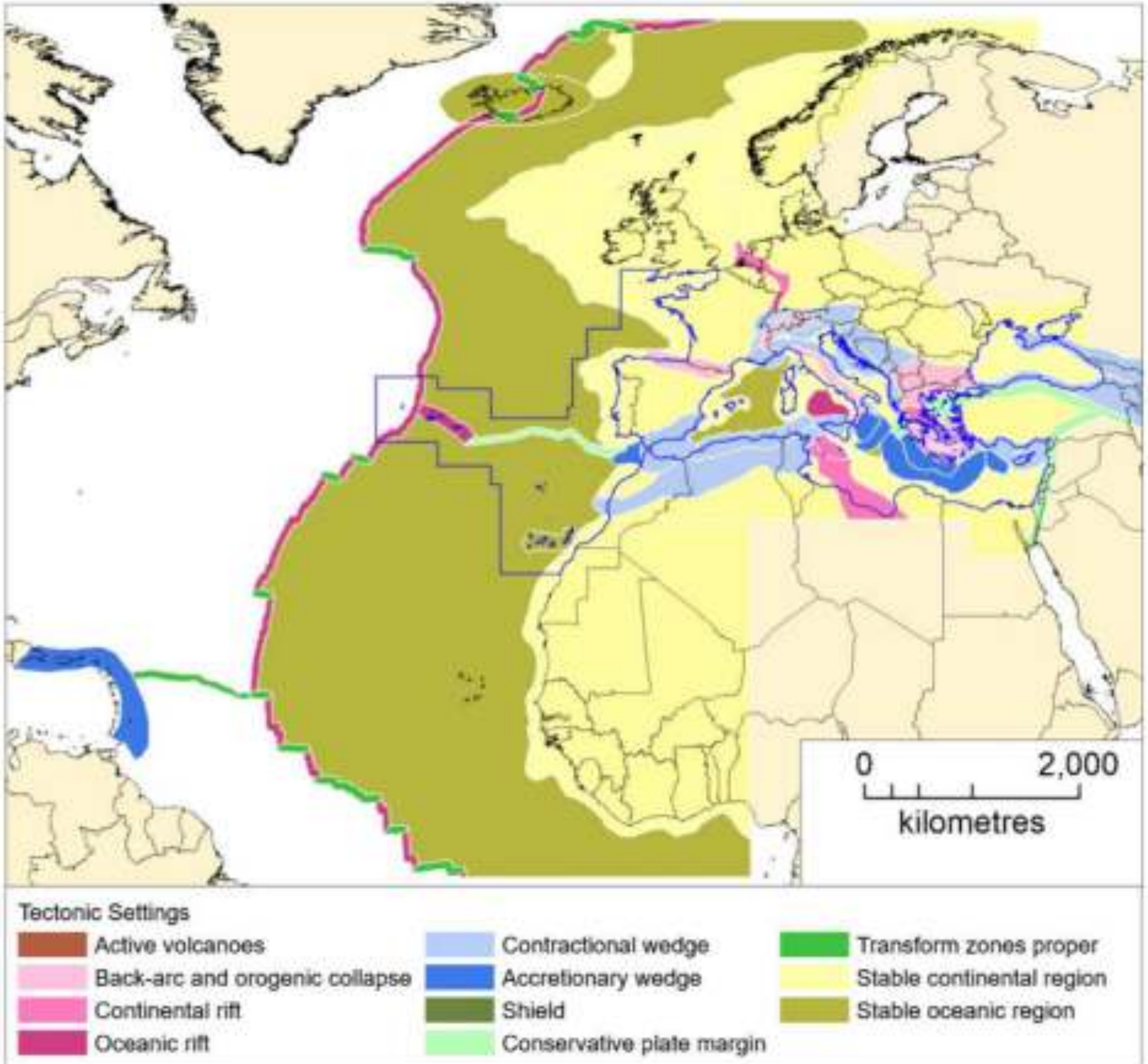
Different groups with different roles

Critical choices based on quantitative input



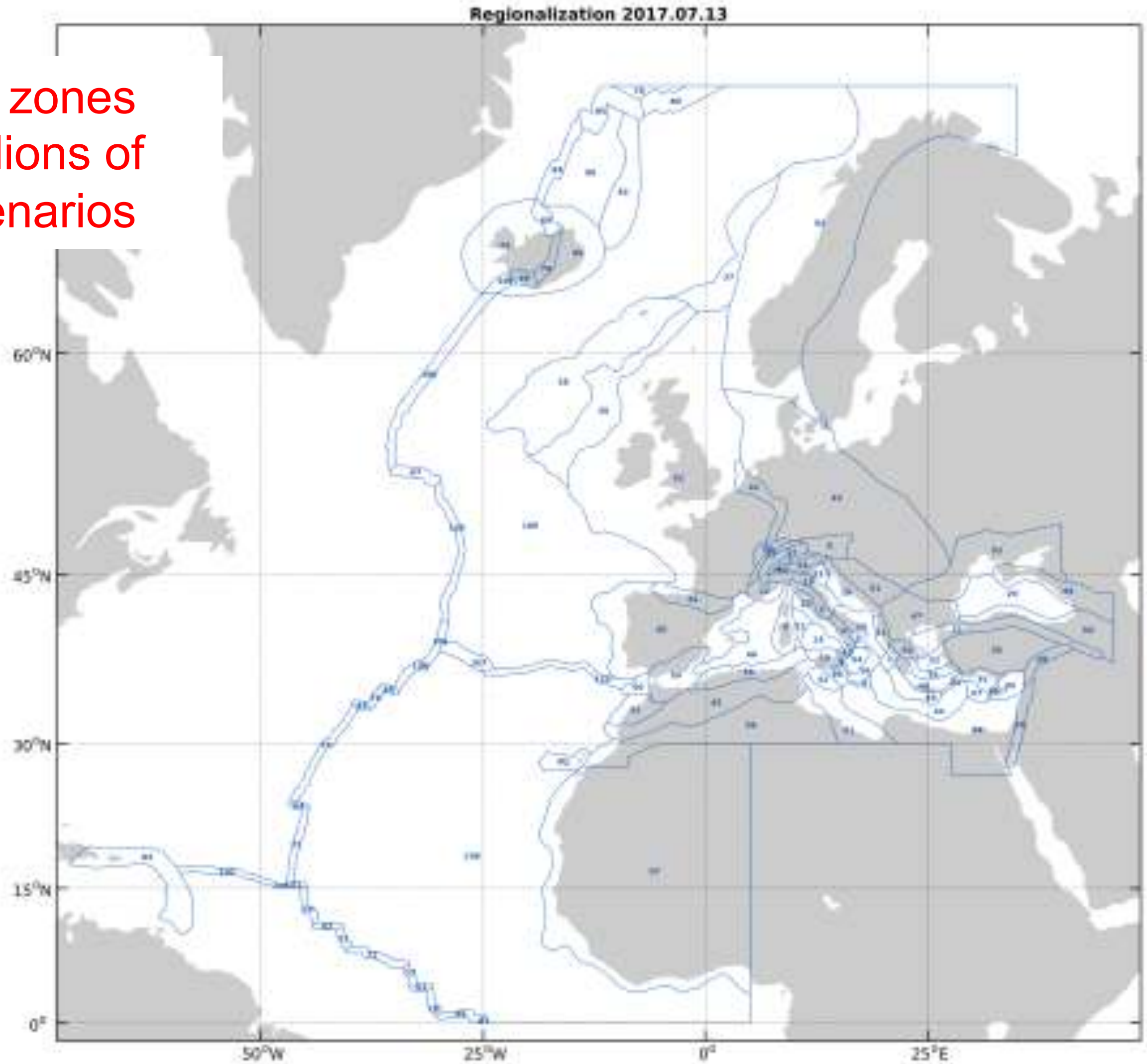
Participatory review during the project

Tectonic zonation

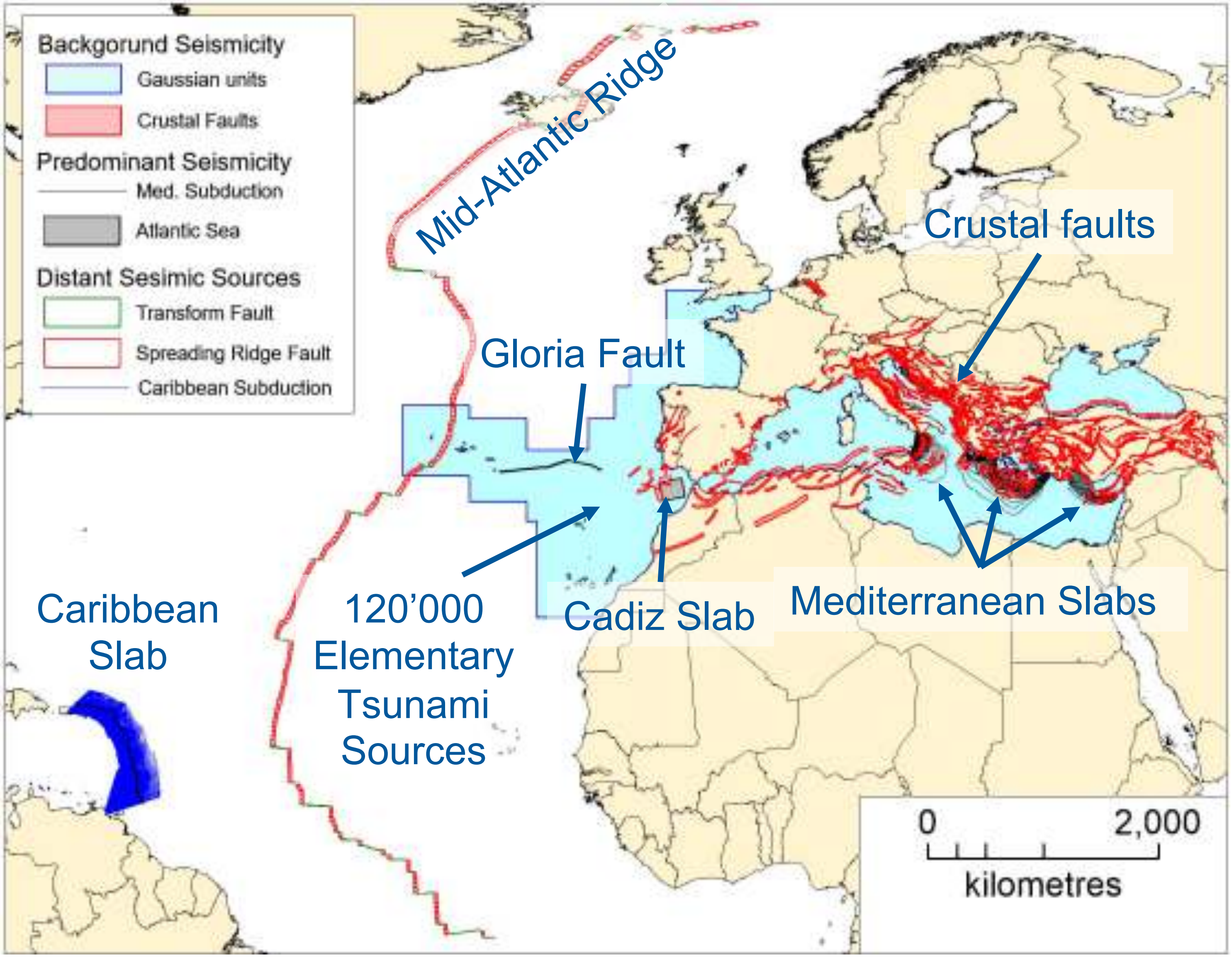


Tectonic zonation

- 110 source zones
- Tens of millions of seismic scenarios

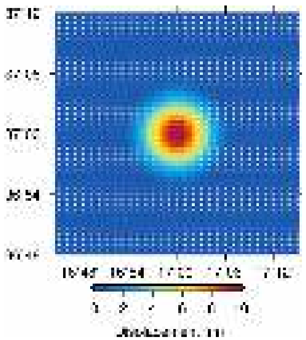


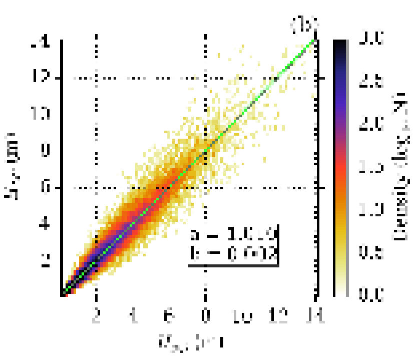
Seismic sources – Tsunami Modeling

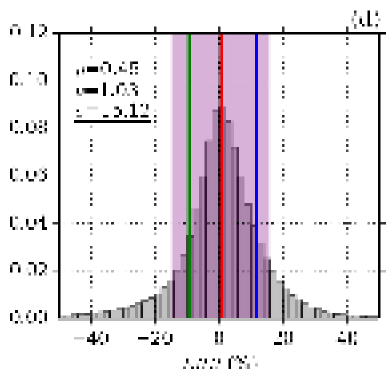


Tsunami Modeling – Elementary Sources

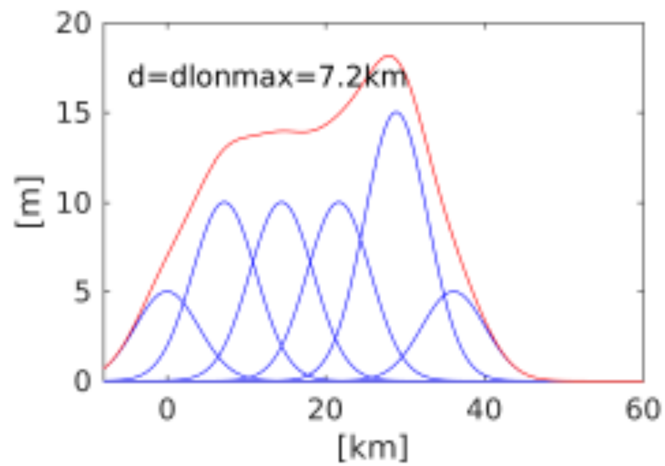
Gaussian elementary sources

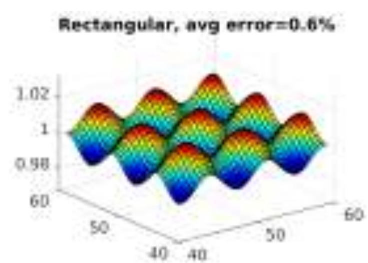


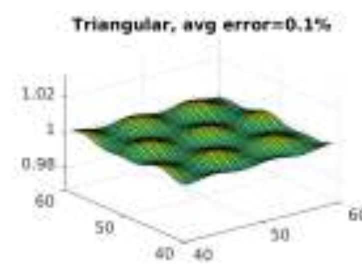




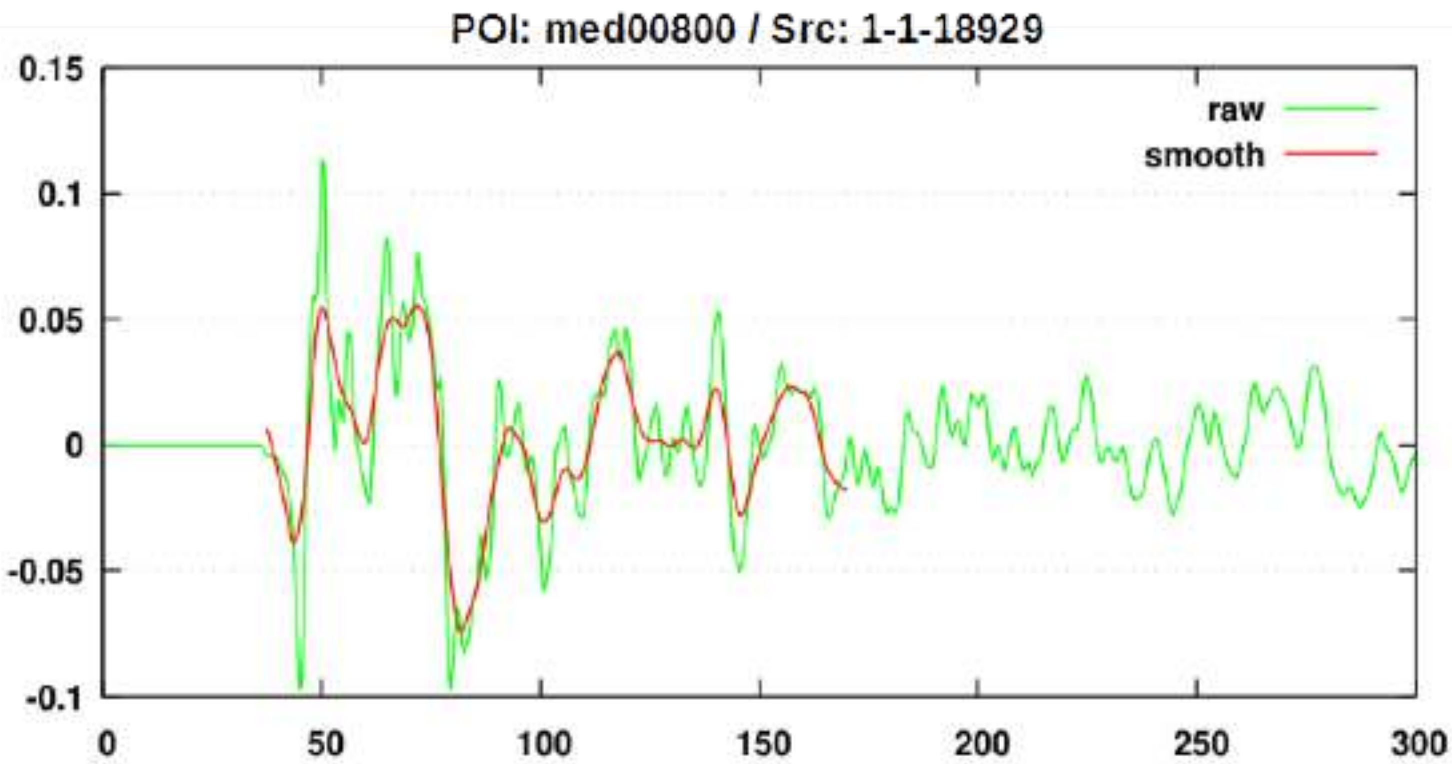
Distribute weights to “fill-up” initial sea surface deformation







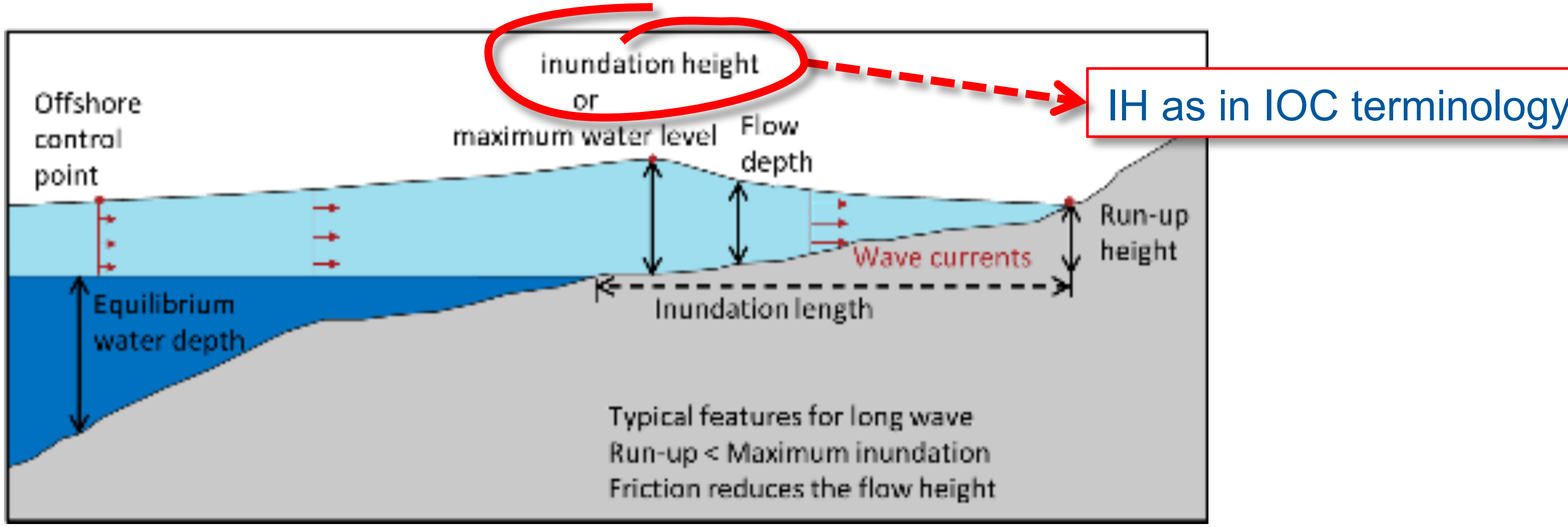
Tsunami Modeling – Combining Mareograms

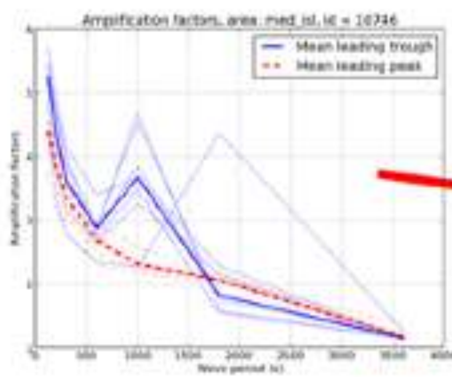


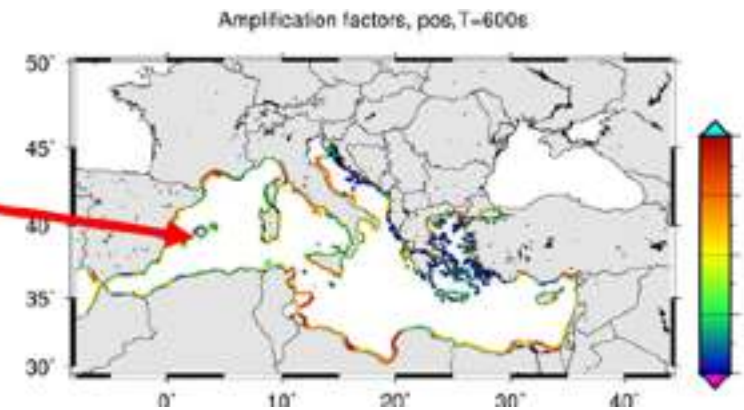
Employing LOWESS filtering with automatic smoothness to derive wave characteristics needed to apply NGI local amplification factors:

- Polarity
- Period

Tsunami Modeling – from Off- to Onshore



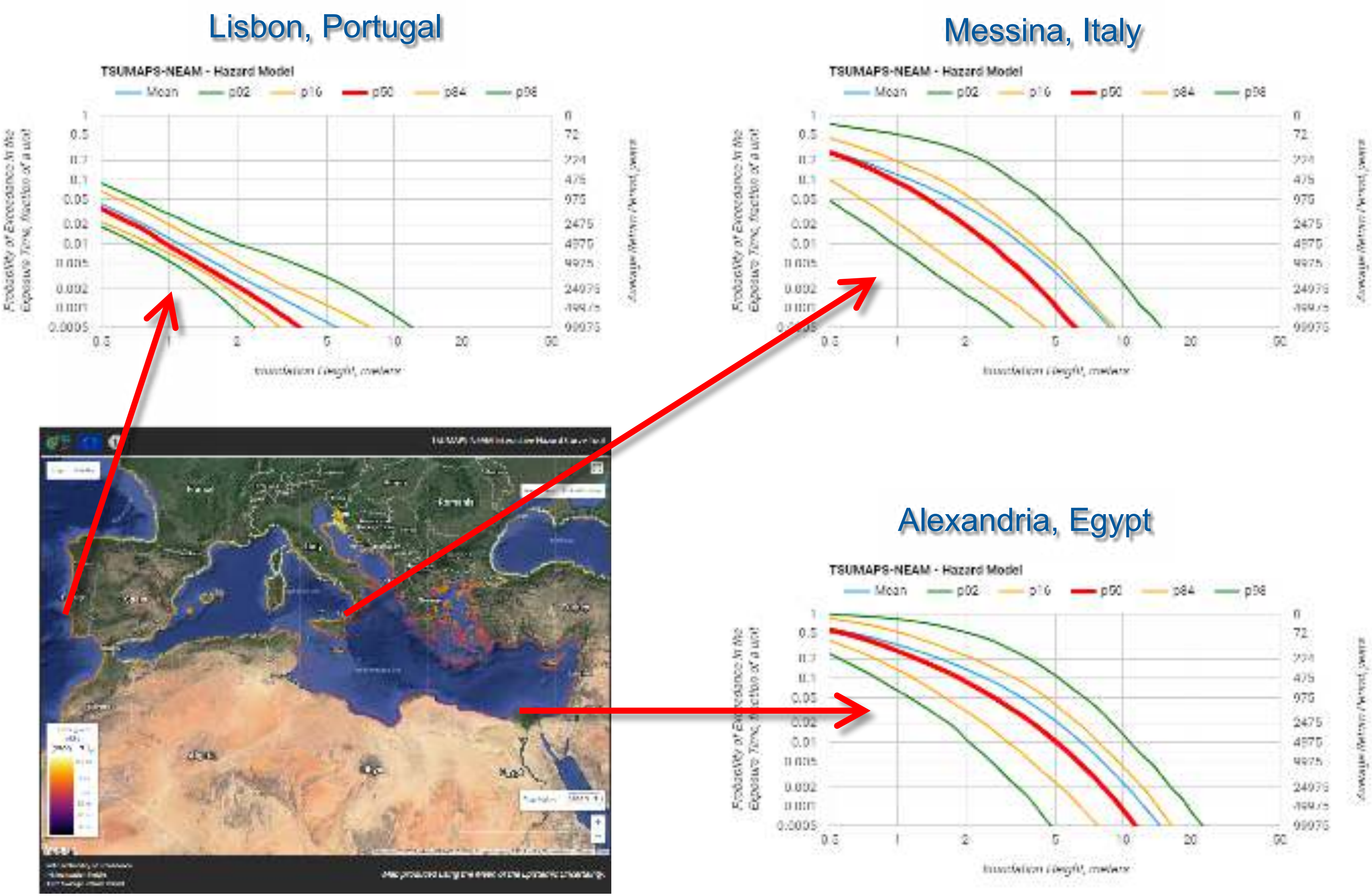




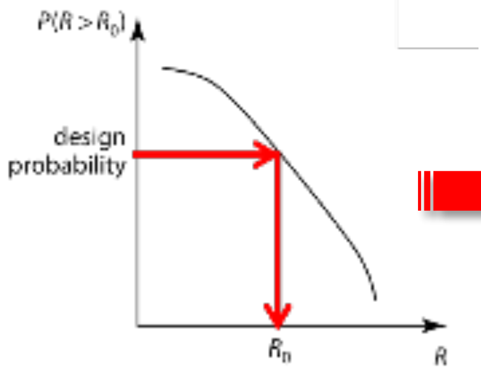
For any given target point

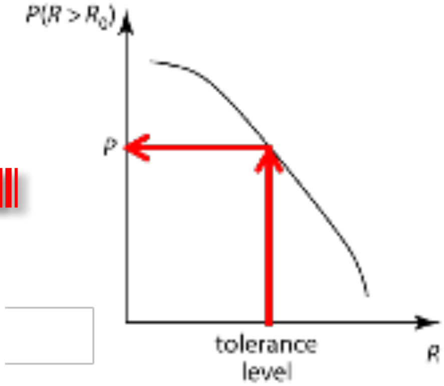
- Extract 40 nearby depth profiles
- Run the 1HD LSW model for all combinations of the wave characteristics (polarity and period) for a selection of profiles
  - **For each run**
    - Measure surface elevation at 50 m depth and shoreline, compute the amplification factors
    - Use the median value 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 IH

Examples of Hazard curves at coastal locations



Results: Probability and Hazard Maps





http://www.tsumaps-neam.eu

Results Factsheet

- Total number of scenarios: ~ 50 Mln
- 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, 2^{nd}, 16^{th}, 50^{th}, 84^{th}, 98^{th} percentiles
- Probability maps for IH 1, 2, 5, 10, 20 meters
- Hazard maps for Average Return Periods of 500, 1000, 2500, 5000, 10000 years
- Interactive Web-based Hazard Map and Curve Tool
  http://www.tsumaps-neam.eu