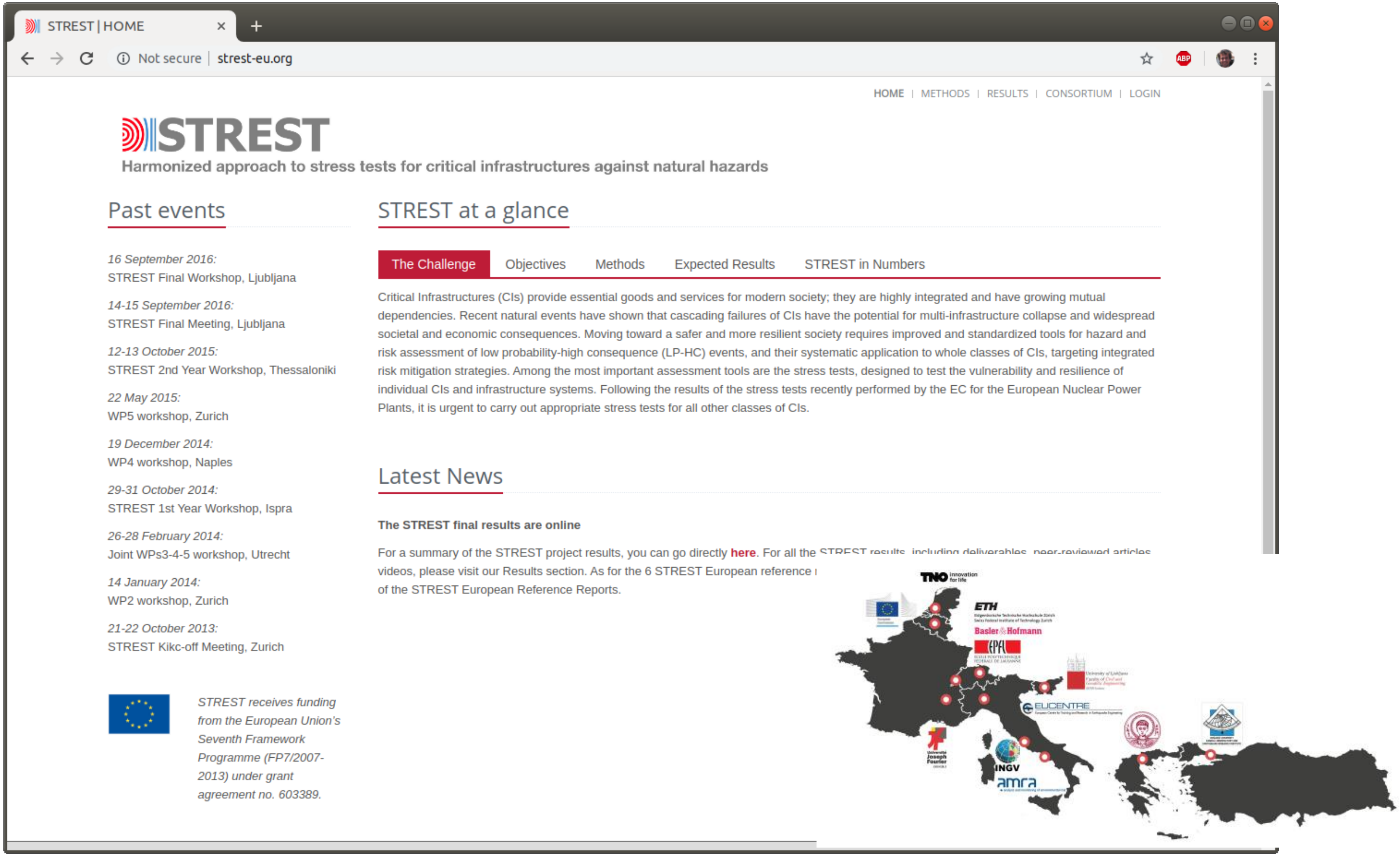
AGITHAR

STREST PROJECT 2013-2016



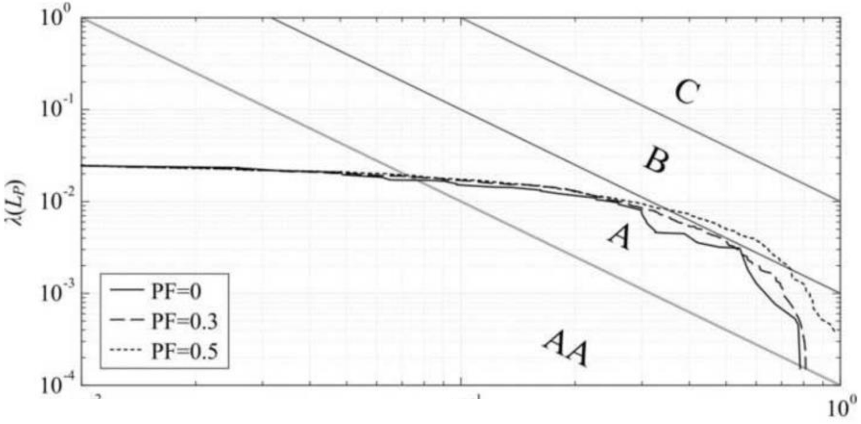
STREST PROJECT 2013-2016

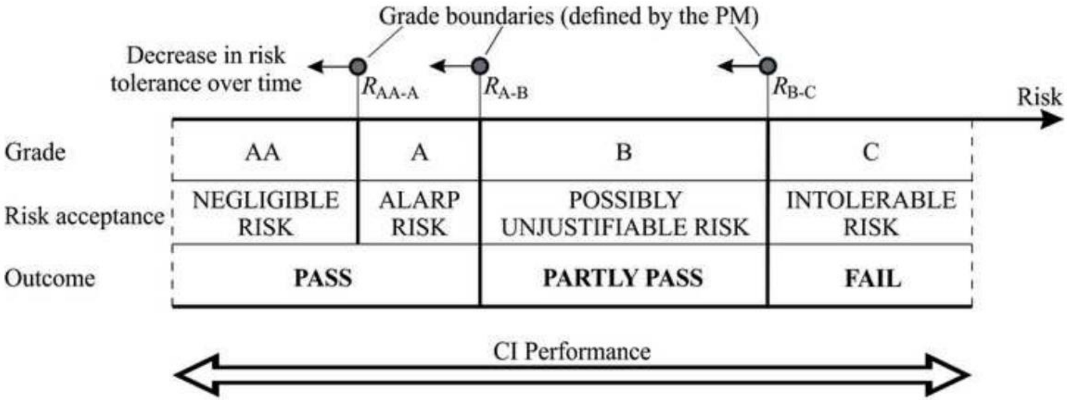
CI-A: Single-site, high-risk, non-nuclear critical infrastructures
CI-B: Geographically distributed, non-nuclear critical infrastructures
CI-C: Multiple-site, low-risk, high-impact, non-nuclear critical infrastructures

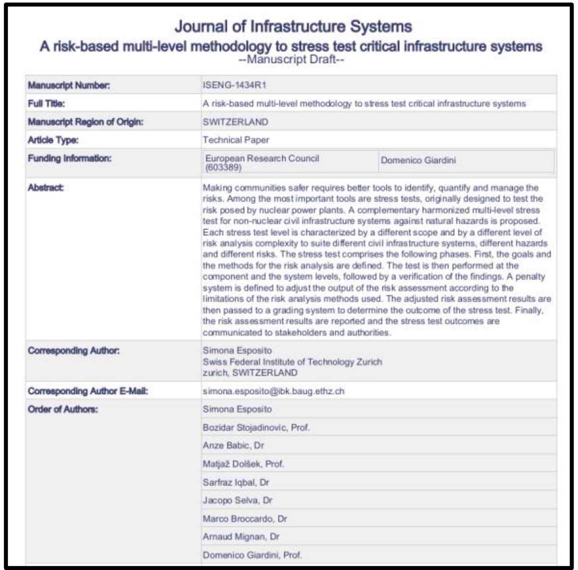
STREST works with key European CIs, to test and apply the developed stress test methodologies to specific CIs, chosen to typify general classes of CIs. Six test sites have been chosen (Fig 1.3):

- CI-A1: Oil refinery and petrochemical plant, Milazzo, Italy (data obtained by AMRA from ENI/Kuwait)
- CI-A2: Large dams, Valais, Switzerland (in collaboration with EPFL and the Office of Dams in the Swiss Federal Office of Energy)
- CI-B1: Major hydrocarbon pipelines, Baku-Tbilisi-Ceyhan (BTC), Turkey (in collaboration with BU and BOTAS Int. Ltd.)
- CI-B2: Gas storage and distribution network, Netherlands (in collaboration with TNO and Gasunie)
- CI-B3: Port infrastructure, Thessaloniki, Greece (in collaboration with AUTH and the Port Authority of Thessaloniki, THPA SA)
- CI-C1: Industrial district, Emilia region, Italy (in collaboration with EUCENTRE and the Confindustria of Piacenza)

- Stress Test Level 1 (ST-L1): single-hazard CI component-only check;
- Stress Test Level 2 (ST-L2): single-hazard CI system-wide risk assessment; and
- Stress Test Level 3 (ST-L3): multi-hazard CI system-wide risk assessment.







Journal of Infrastructure Systems

A risk-based multi-level methodology to stress test critical infrastructure systems

--Manuscript Draft--

Manuscript Number:	ISENG-1434R1	
Full Title:	A risk-based multi-level methodology to stress test critical infrastructure systems	
Manuscript Region of Origin:	SWITZERLAND	
Article Type:	Technical Paper	
Funding Information:	European Research Council (603389)	Domenico Giardini
Abstract:	Making communities safer requires better tools to identify, quantify and manage the risks. Among the most important tools are stress tests, originally designed to test the risk posed by nuclear power plants. A complementary harmonized multi-level stress test for non-nuclear civil infrastructure systems against natural hazards is proposed. Each stress test level is characterized by a different scope and by a different level of risk analysis complexity to suite different civil infrastructure systems, different hazards and different risks. The stress test comprises the following phases. First, the goals and the methods for the risk analysis are defined. The test is then performed at the component and the system levels, followed by a verification of the findings. A penalty system is defined to adjust the output of the risk assessment according to the limitations of the risk analysis methods used. The adjusted risk assessment results are then passed to a grading system to determine the outcome of the stress test. Finally, the risk assessment results are reported and the stress test outcomes are communicated to stakeholders and authorities.	
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	Bozidar Stojadinovic, Prof.	
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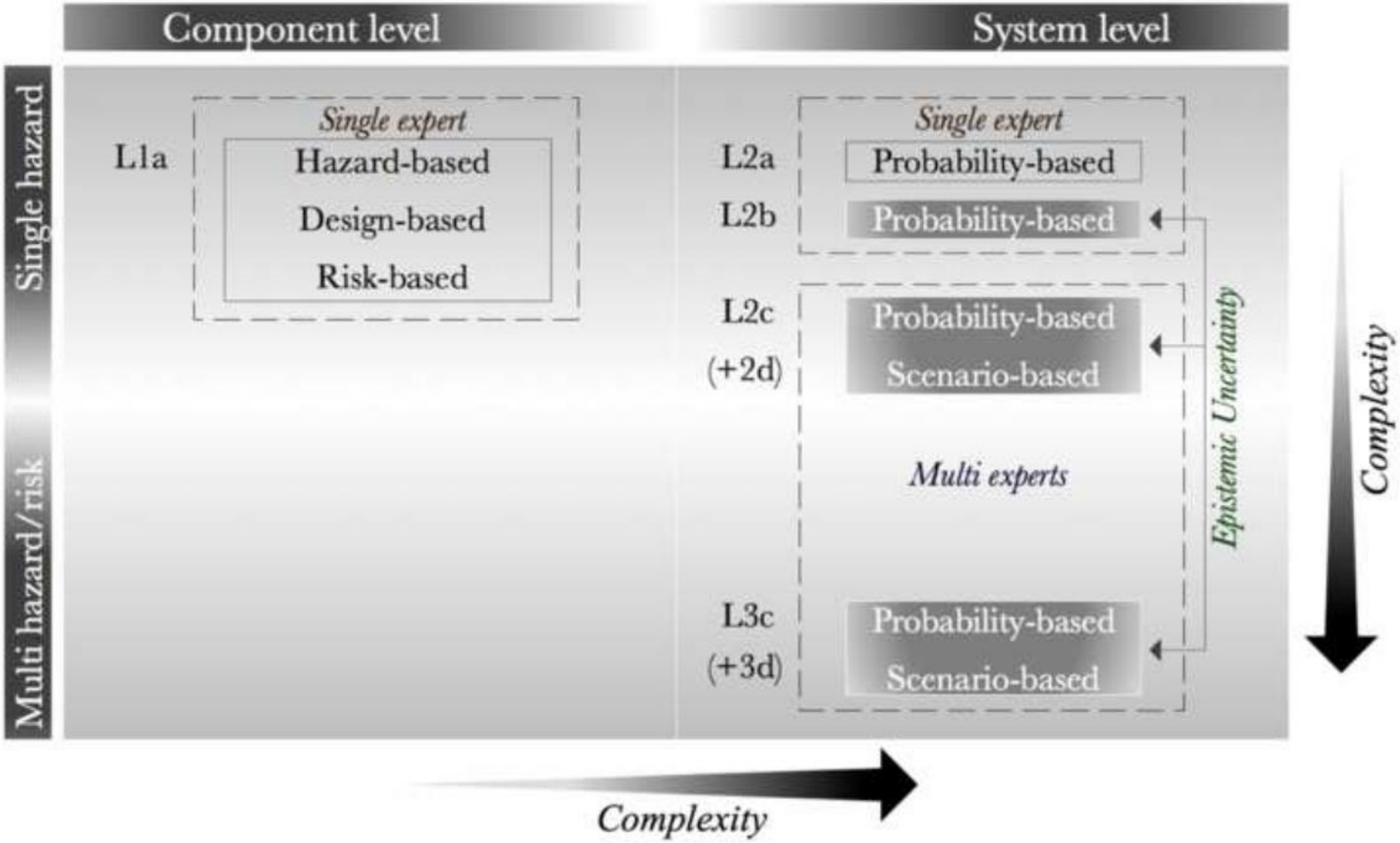
	Jacopo Selva, Dr	
	Marco Broccardo, Dr	
	Arnaud Mignan, Dr	
	Domenico Giardini, Prof.	

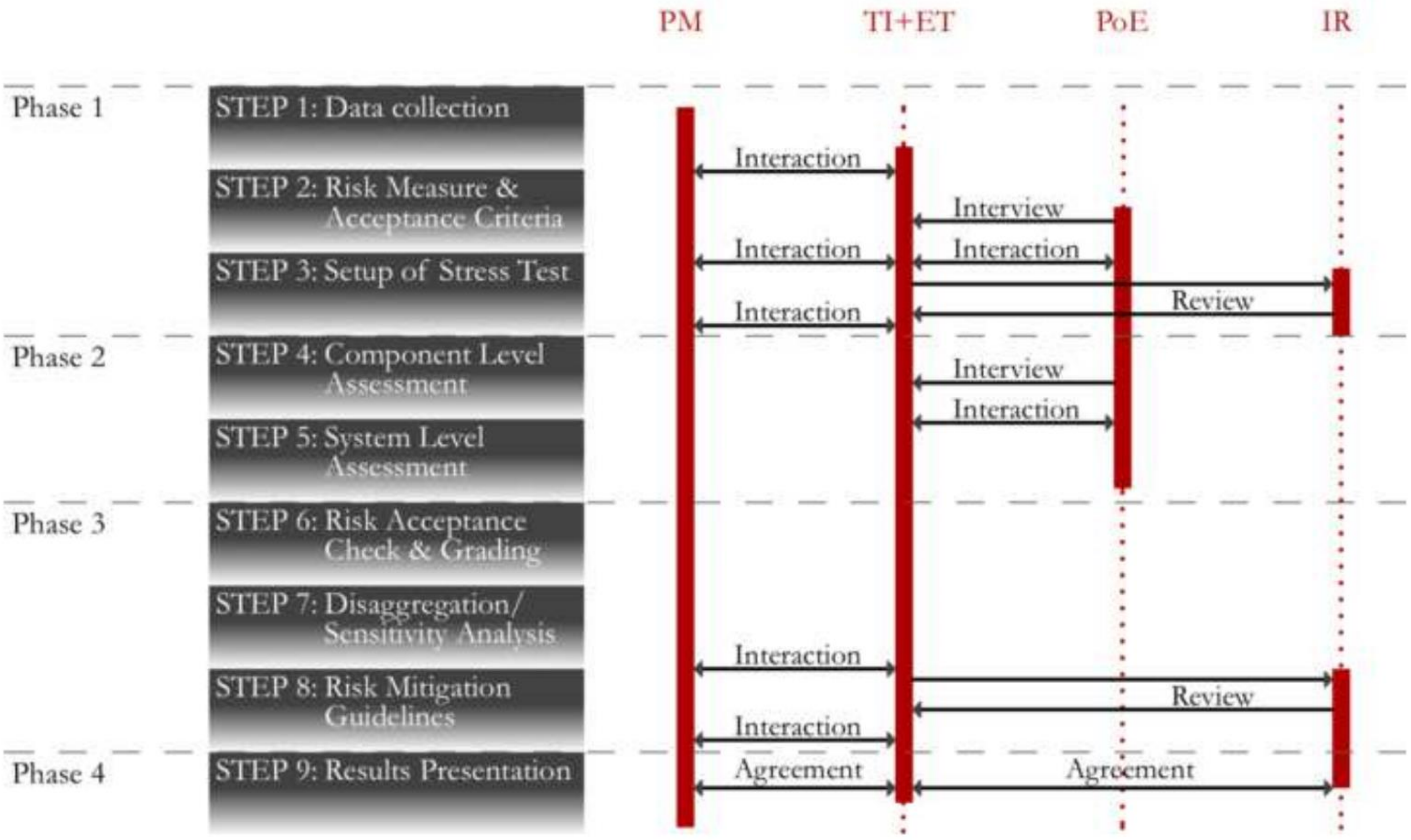
STREST PROJECT 2013-2016

Increasing level...

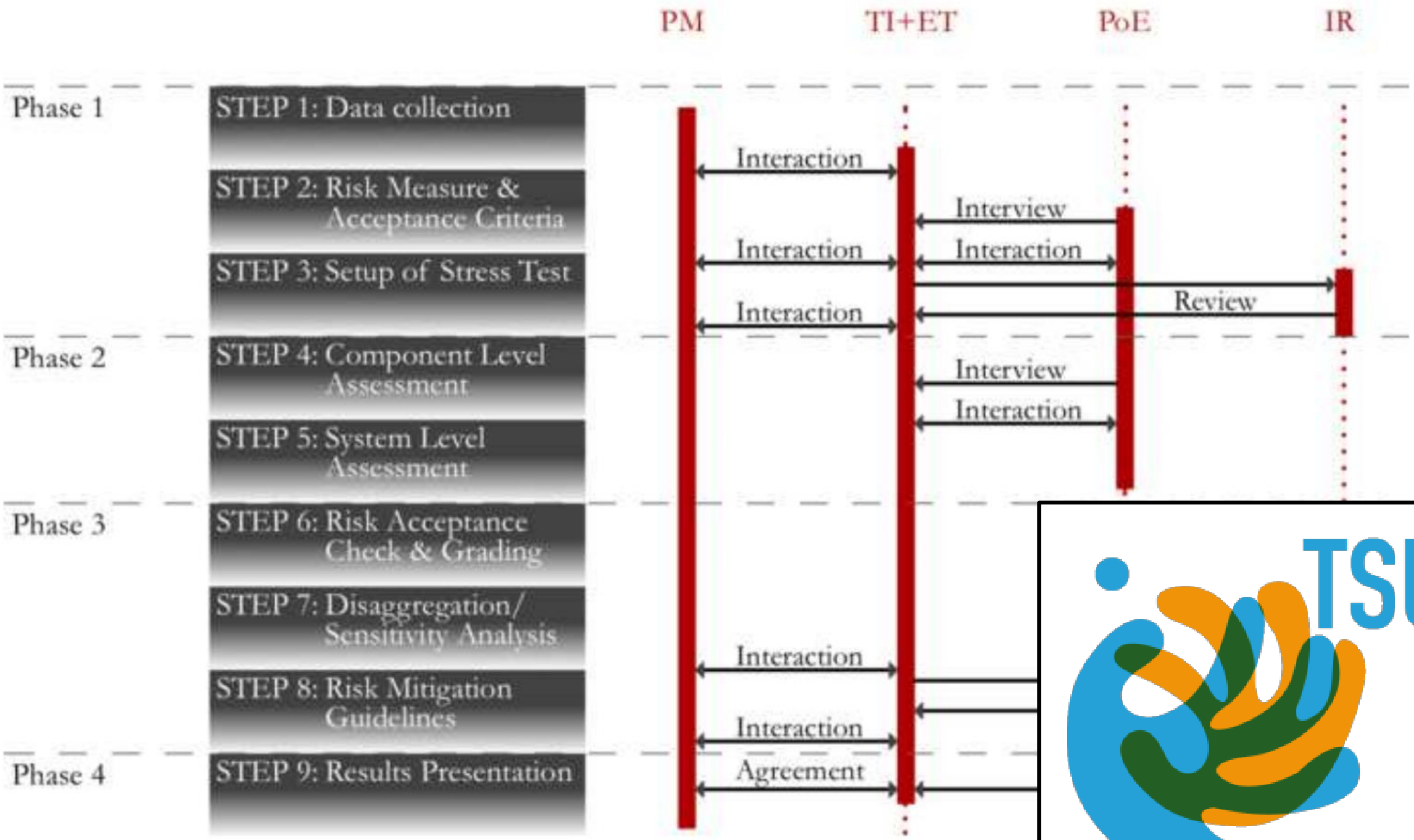
Single components → systemic vulnerability
Single hazard → multi-hazard
Single expert → multiple experts



STREST PROJECT 2013-2016



STREST PROJECT 2013-2016



TSUMAPS NEAM
Probabilistic TSUnami Hazard MAPS for the NEAM Region

FOCUS POINTS

1) From regional to local PTHA

2) From single components to systemic vulnerability and risk of complex systems

3) From single to multi-hazard risk quantification

4) From single expert to multiple-experts for managing subjective choices

FOCUS POINTS

1) From regional to local PTHA

2) From single components to systemic vulnerability and risk of complex systems

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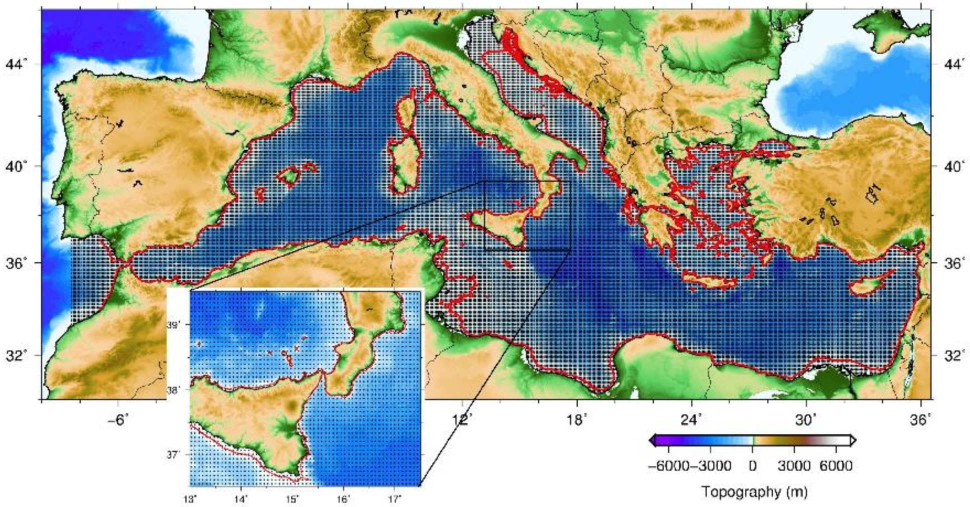
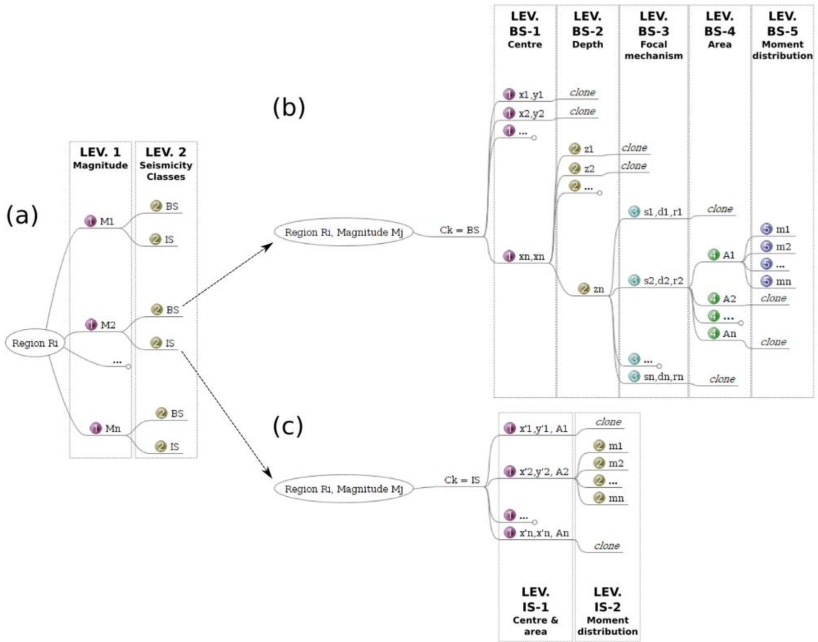
4) From single expert to multiple-experts for managing subjective choices

1. FROM REGIONAL TO LOCAL PTHA





Geophysical Journal International

Geophys. J. Int. (2016) **205**, 1780–1803
Advance Access publication 2016 March 21
GJI Seismology

doi: 10.1093/gji/ggw107

Quantification of source uncertainties in Seismic Probabilistic Tsunami Hazard Analysis (SPTHA)

J. Selva,[1] R. Tonini,[2] I. Molinari,[3] M.M. Tiberti,[2] F. Romano,[2] A. Grezio,[1] D. Melini,[2] A. Piatanesi,[2] R. Basili[2] and S. Lorito[2]

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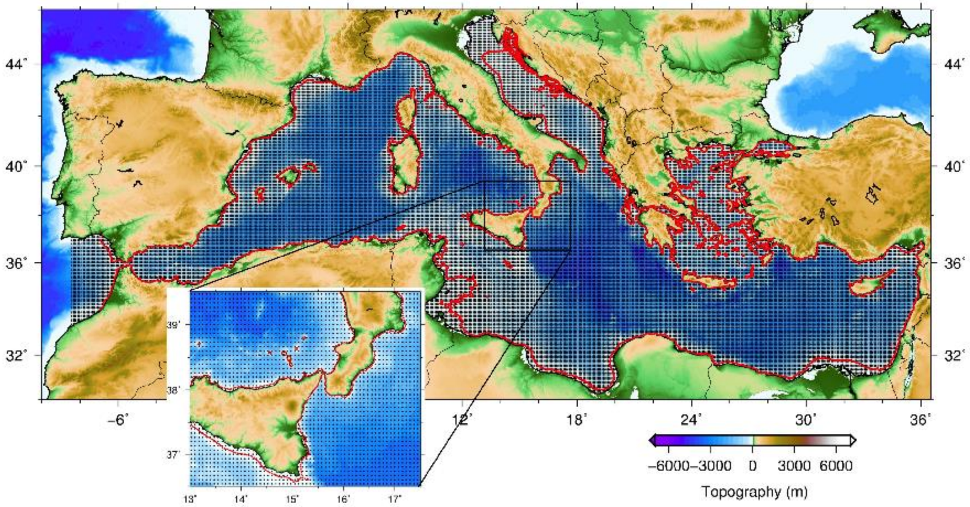
Accepted 2016 March 17. Received 2016 March 17; in original form 2015 August 9

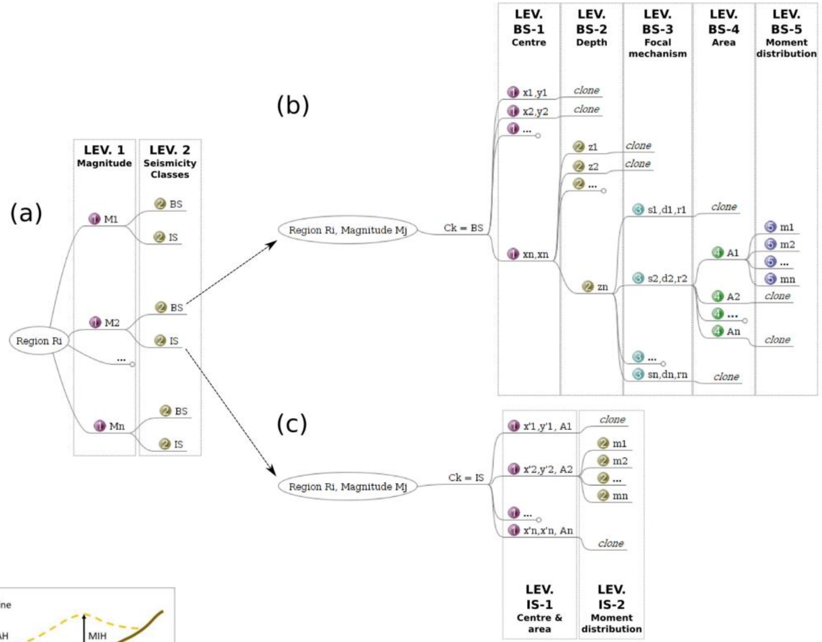
SUMMARY

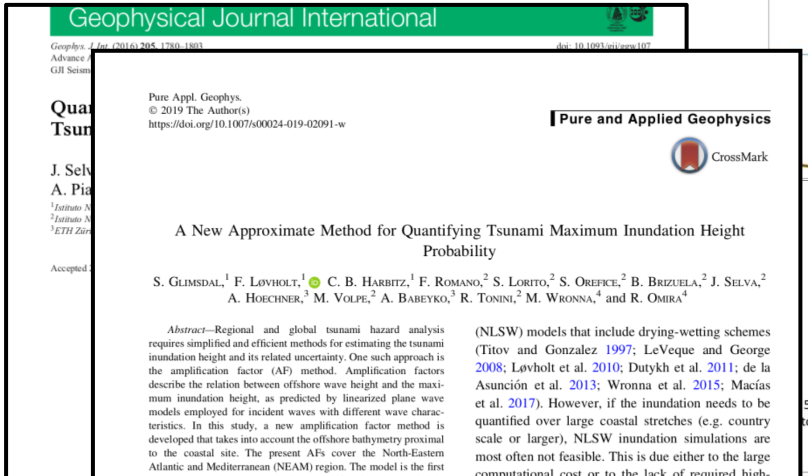
We propose a procedure for uncertainty quantification in Probabilistic Tsunami Hazard Analysis (PTHA), with a special emphasis on the uncertainty related to statistical modelling of the earthquake source in Seismic PTHA (SPTHA), and on the separate treatment of subduction and crustal earthquakes (treated as background seismicity). An event tree approach and ensemble modelling are used in spite of more classical approaches, such as the hazard integral and the logic tree. This procedure consists of four steps: (1) exploration of aleatory uncertainty through an event tree, with alternative implementations for exploring epistemic uncertainty; (2) numerical computation of tsunami generation and propagation up to a given offshore isobath; (3) (optional) site-specific quantification of inundation; (4) simultaneous quantification of aleatory and epistemic uncertainty through ensemble modelling. The proposed procedure is general and independent of the kind of tsunami source considered; however, we implement

~10^7 sources
~ 10^2 alternative implementations

1. FROM REGIONAL TO LOCAL PTHA







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Pure and Applied Geophysics

CrossMark

A New Approximate Method for Quantifying Tsunami Maximum Inundation Height Probability

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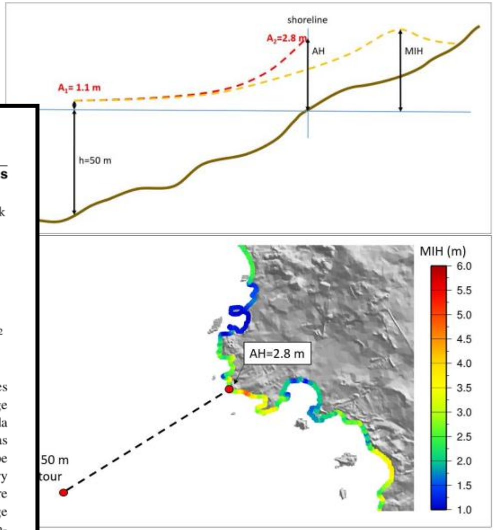
Abstract—Regional and global tsunami hazard analysis requires simplified and efficient methods for estimating the tsunami inundation height and its related uncertainty. One such approach is the amplification factor (AF) method. Amplification factors describe the relation between offshore wave height and the maximum inundation height, as predicted by linearized plane wave models employed for incident waves with different wave characteristics. In this study, a new amplification factor method is developed that takes into account the offshore bathymetry proximal to the coastal site. The present AFs cover the North-Eastern Atlantic and Mediterranean (NEAM) region. The model is the first

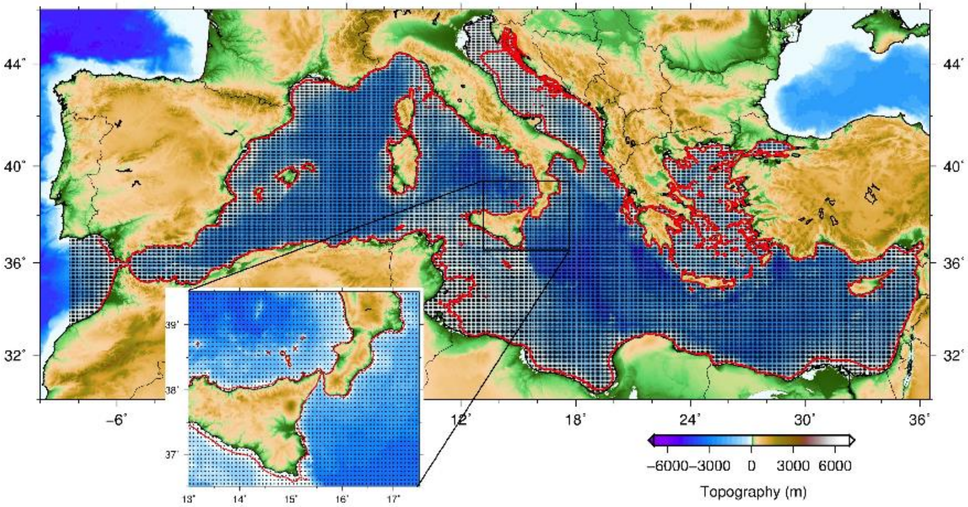
(NLSW) models that include drying-wetting schemes (Titov and Gonzalez 1997; LeVeque and George 2008; Løvholt et al. 2010; Dutykh et al. 2011; de la Asunción et al. 2013; Wronna et al. 2015; Macías et al. 2017). However, if the inundation needs to be quantified over large coastal stretches (e.g. country scale or larger), NLSW inundation simulations are most often not feasible. This is due either to the large computational cost or to the lack of required high-

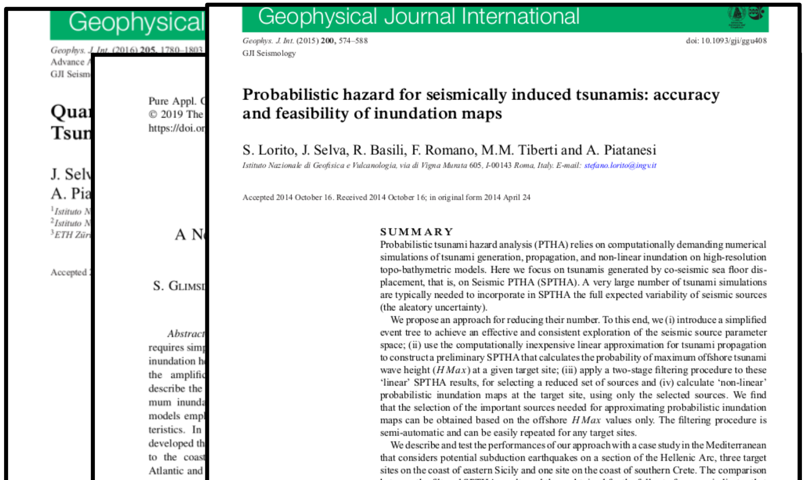


~10^7 sources
~ 10^2 alternative implementations

Propagation to 50m
Amplification distribution on coast
(Glimsdal et al., 2019)

1. FROM REGIONAL TO LOCAL PTHA




Geophysical Journal International

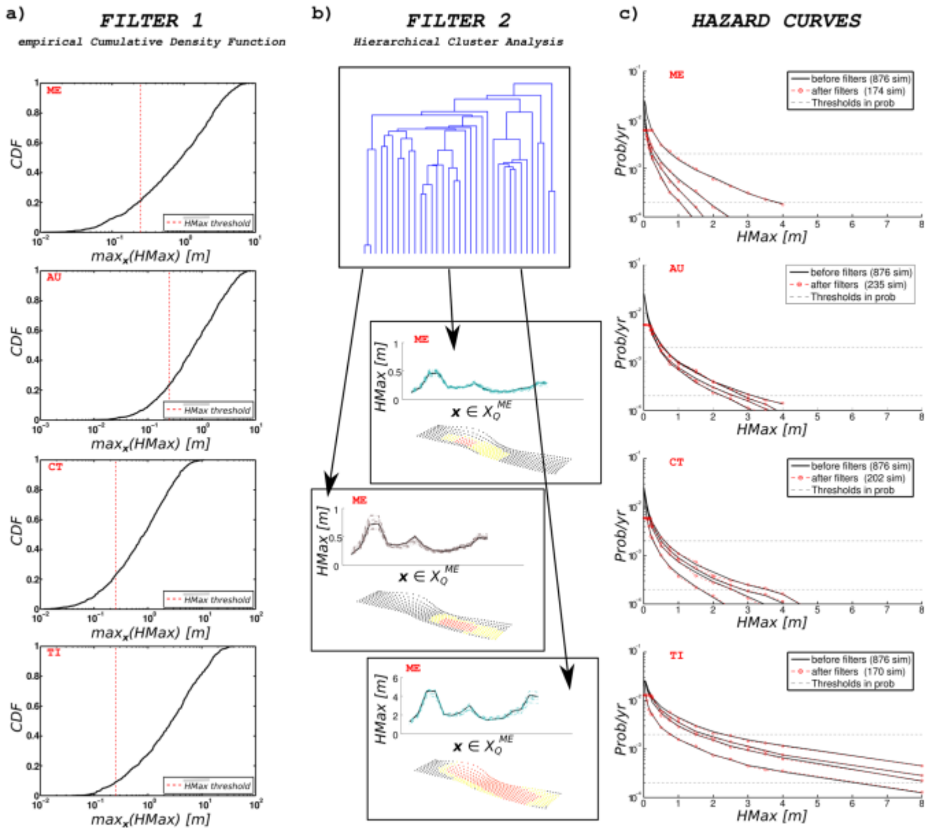
Geophys. J. Int. (2015) 200, 574–588
doi: 10.1093/gji/ggu408
GJI Seismology

Probabilistic hazard for seismically induced tsunamis: accuracy and feasibility of inundation maps

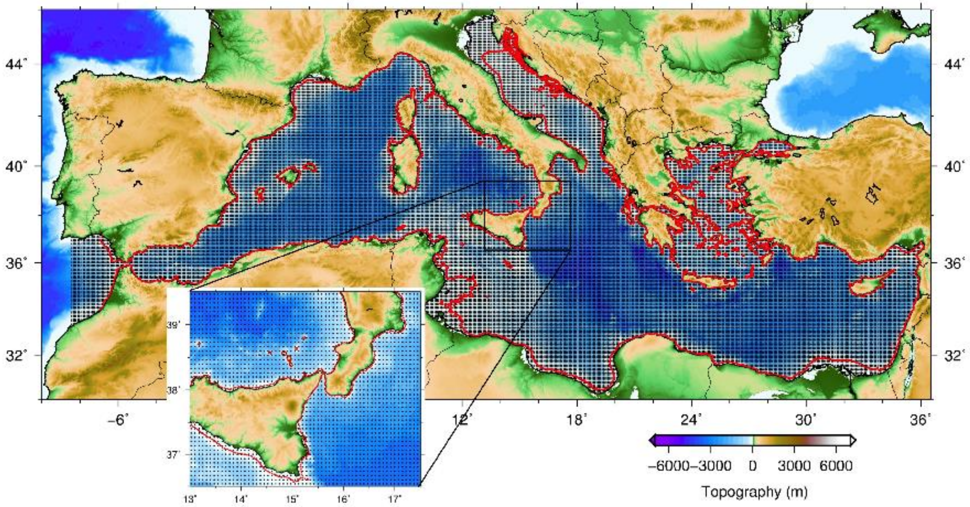
S. Lorito, J. Selva, R. Basili, F. Romano, M.M. Tiberti and A. Piatanesi
Istituto Nazionale di Geofisica e Vulcanologia, via di Vigna Murata 605, I-00143 Roma, Italy. E-mail: stefano.lorito@ingv.it

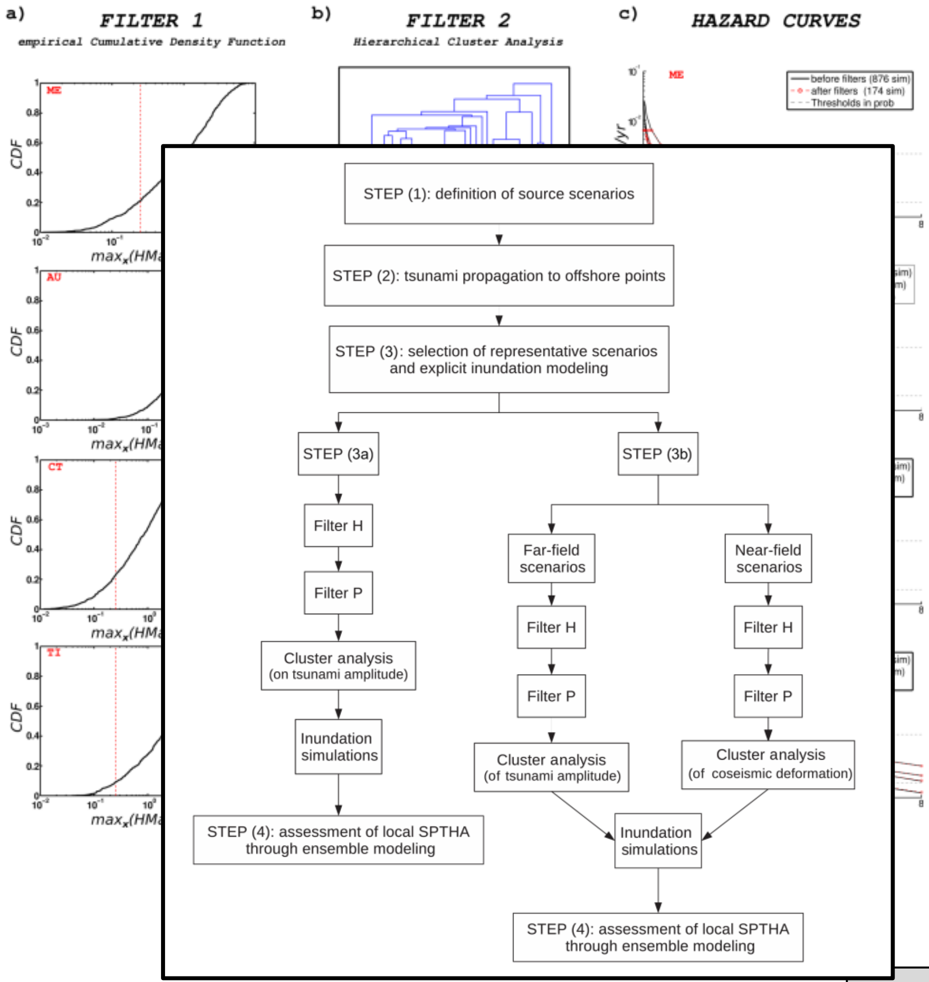
Accepted 2014 October 16. Received 2014 October 16; in original form 2014 April 24

SUMMARY
Probabilistic tsunami hazard analysis (PTHA) relies on computationally demanding numerical simulations of tsunami generation, propagation, and non-linear inundation on high-resolution topo-bathymetric models. Here we focus on tsunamis generated by co-seismic sea floor displacement, that is, on Seismic PTHA (SPTHA). A very large number of tsunami simulations are typically needed to incorporate in SPTHA the full expected variability of seismic sources (the aleatory uncertainty).
We propose an approach for reducing their number. To this end, we (i) introduce a simplified event tree to achieve an effective and consistent exploration of the seismic source parameter space; (ii) use the computationally inexpensive linear approximation for tsunami propagation to construct a preliminary SPTHA that calculates the probability of maximum offshore tsunami wave height ($HMax$) at a given target site; (iii) apply a two-stage filtering procedure to these 'linear' SPTHA results, for selecting a reduced set of sources and (iv) calculate 'non-linear' probabilistic inundation maps at the target site, using only the selected sources. We find that the selection of the important sources needed for approximating probabilistic inundation maps can be obtained based on the offshore $HMax$ values only. The filtering procedure is semi-automatic and can be easily repeated for any target site.
We describe and test the performances of our approach with a case study in the Mediterranean that considers potential subduction earthquakes on a section of the Hellenic Arc, three target sites on the coast of eastern Sicily and one site on the coast of southern Crete. The comparison

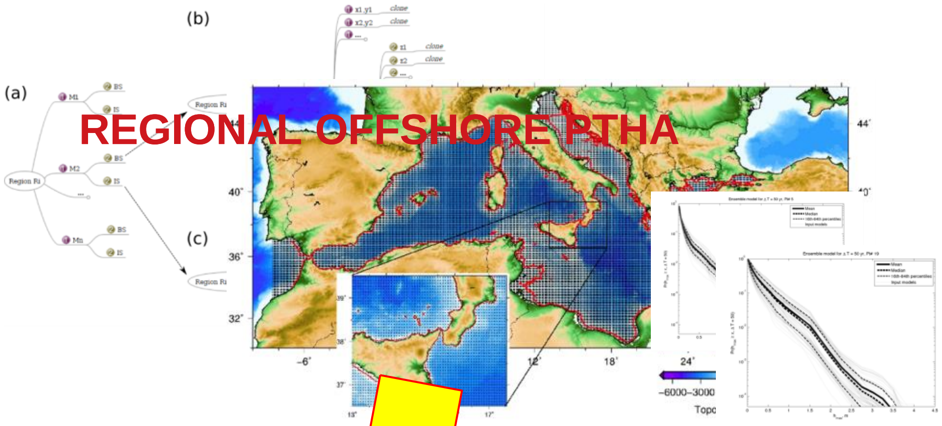


1. FROM REGIONAL TO LOCAL PTHA

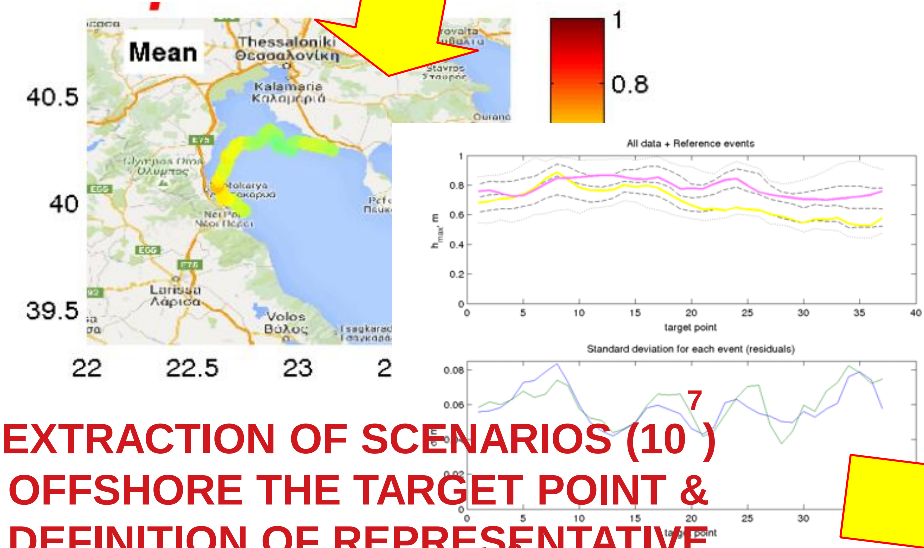




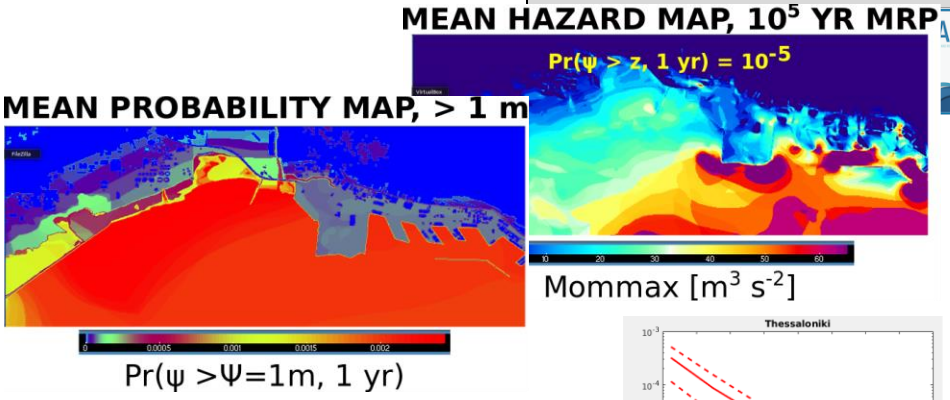
1. FROM REGIONAL TO LOCAL PTHA

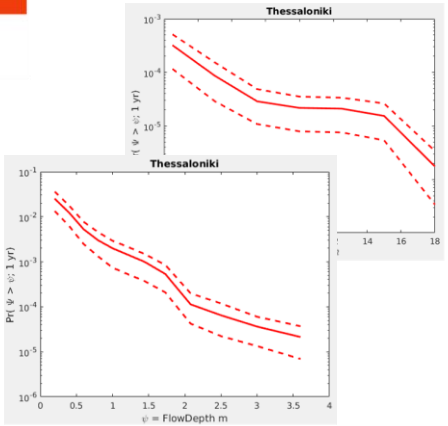


REGIONAL OFFSHORE PTHA

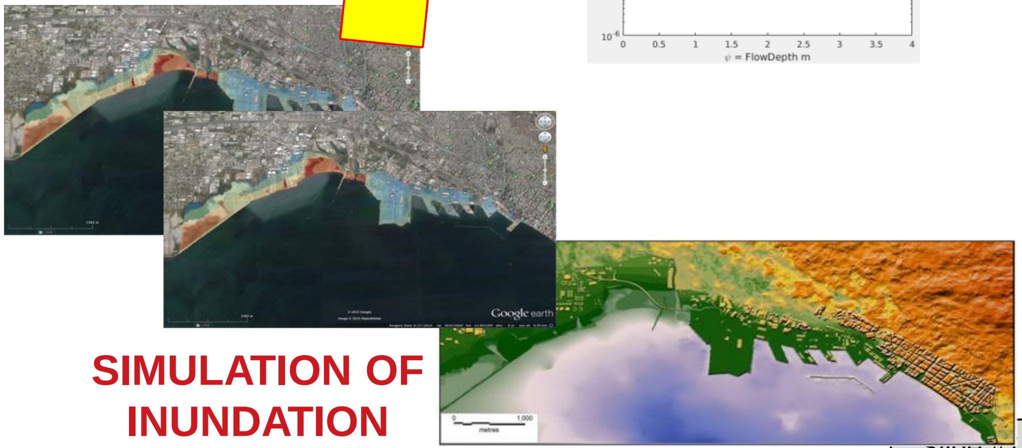


EXTRACTION OF SCENARIOS (10^7) OFFSHORE THE TARGET POINT & DEFINITION OF REPRESENTATIVE SCENARIOS (10^5)





LOCAL HAZARD



SIMULATION OF INUNDATION

FOCUS POINTS

1) From regional to local PTHA

2) From single components to systemic vulnerability and risk of complex systems

3) From single to multi-hazard risk quantification

4) From single expert to multiple-experts for managing subjective choices

3. From single-component to system vulnerability

SYNER-G

$$f(x) = f_{SYS|PhVM}(x_{SYS}|x_{PhVM})\, f_{PhVM|SH}(x_{PhVM}|x_{SH}) \times f_{SH}(x_{SH}) \quad (1)$$

COMPUTER-AIDED CIVIL AND INFRASTRUCTURE ENGINEERING

Computer-Aided Civil and Infrastructure Engineering **30** (2015) 524–540

Systemic Seismic Risk Assessment of Road Networks Considering Interactions with the Built Environment

Sotirios Argyroudis*

Department of Civil Engineering, Aristotle University of Thessaloniki, Thessaloniki, Greece

Jacopo Selva

Istituto Nazionale di Geofisica e Vulcanologia, Bologna, Italy

Pierre Gehl

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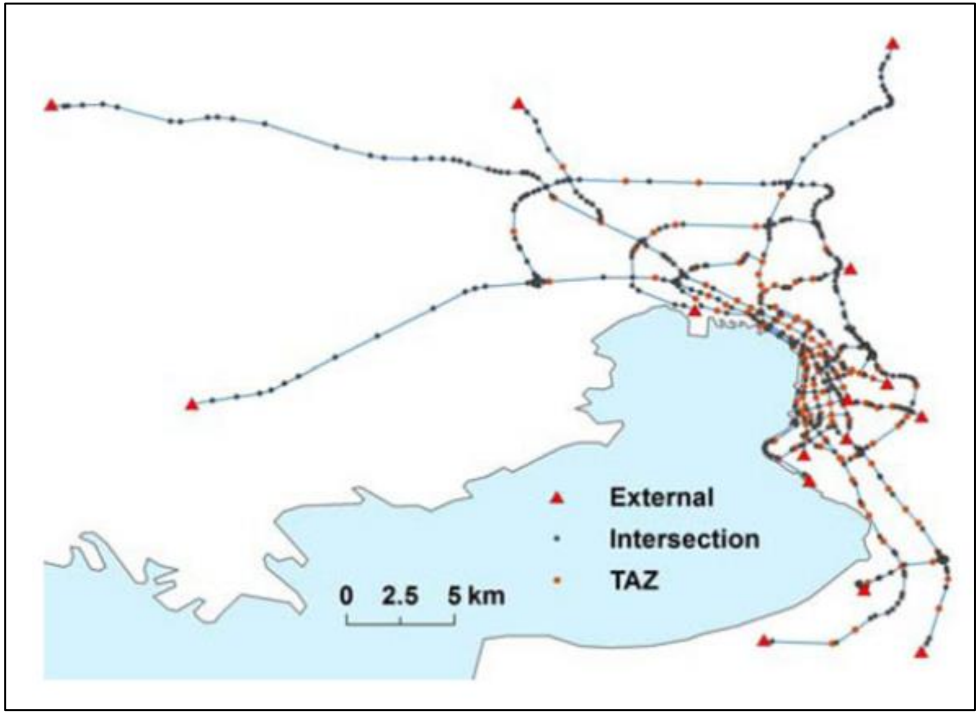
&

Kyriazis Pitilakis

Department of Civil Engineering, Aristotle University of Thessaloniki, Thessaloniki, Greece

Abstract: *This article presents an integrated approach for the probabilistic systemic risk analysis of a road network considering spatial seismic hazard with correlation of ground motion intensities, vulnerability of the network components, and the effect of interactions within the area is calculated, specifically focusing on the short-term impact of seismic events (just after the earthquake). The potential of road blockages due to collapses of adjacent buildings and overpass bridges is analyzed, trying to individuate possible criticalities related to specific compo-*



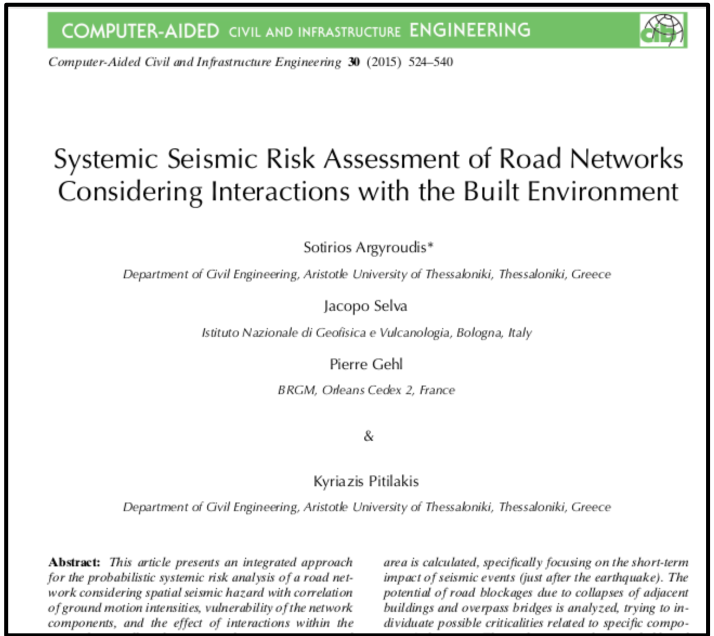
→ *hazard spatial distribution should be realistic:*

→ *single scenarios sampled e modeled separately*

→ *spatial correlation should be kept*

→ *single configurations of damages should be sampled (not only average risk)*

→ *all event-based risks should recombined probabilistically*



COMPUTER-AIDED CIVIL AND INFRASTRUCTURE ENGINEERING

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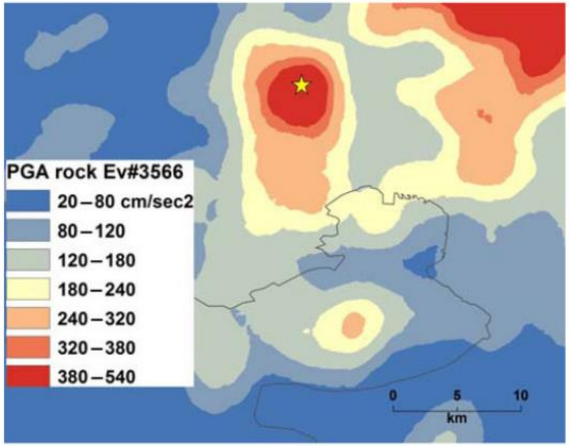

3. From single-component to system vulnerability

AGITHAR

SYNER-G

→ *hazard spatial distribution should be realistic:*

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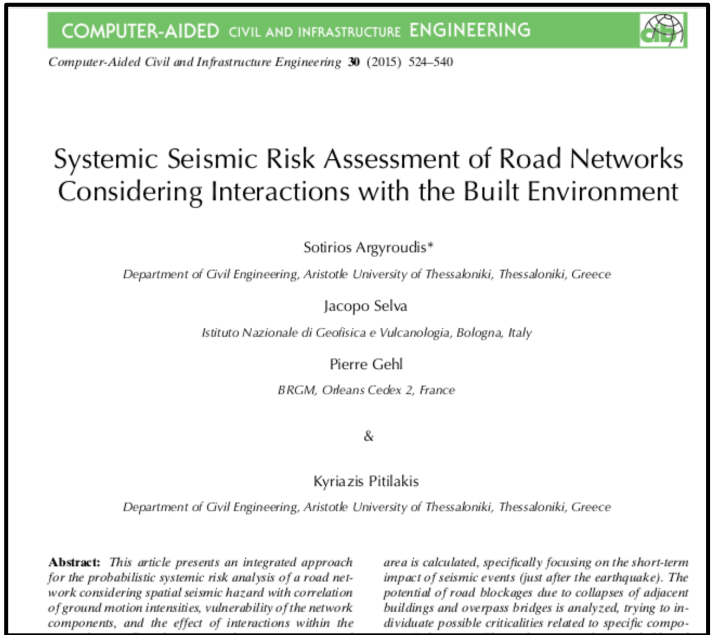

COMPUTER-AIDED CIVIL AND INFRASTRUCTURE ENGINEERING

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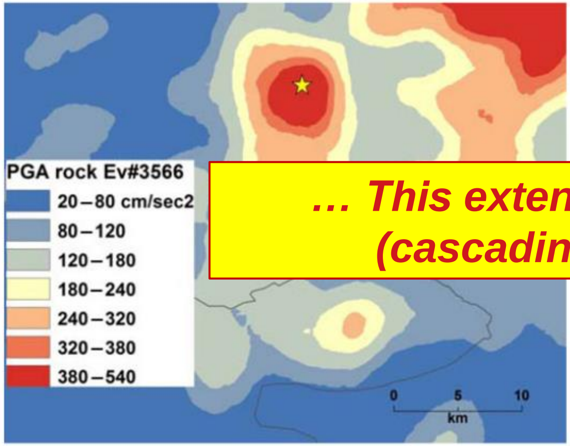


… This extends to multi-hazard (cascading events) risk!!

FOCUS POINTS

1) From regional to local PTHA

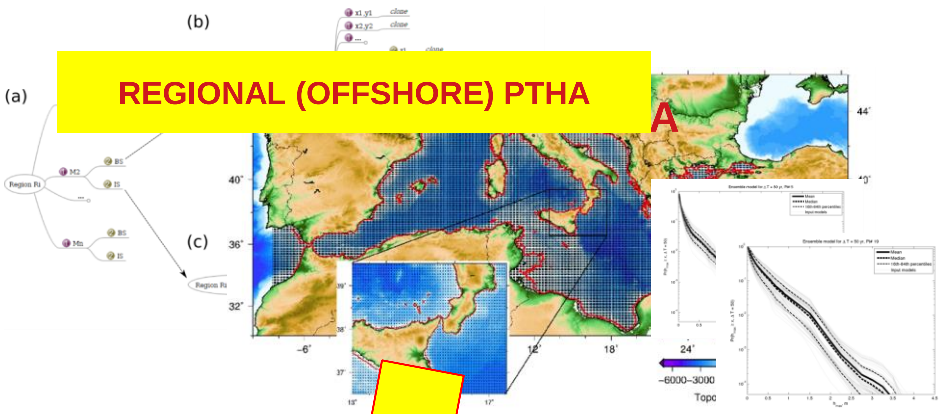
2) From single components to systemic vulnerability and risk of complex systems

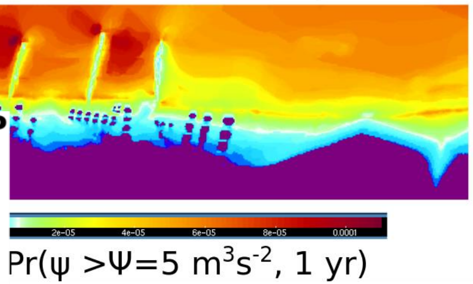
3) From single to multi-hazard risk quantification

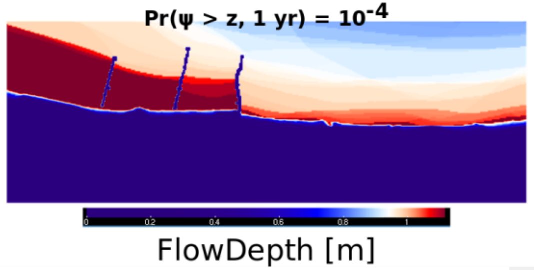
4) From single expert to multiple-experts for managing subjective choices

3. FROM SINGLE TO MULTI-HAZARD RISK

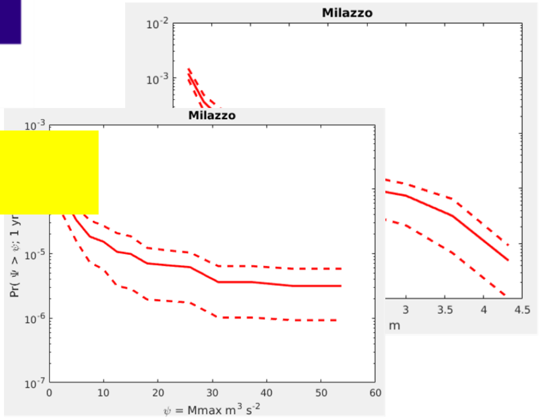
REGIONAL (OFFSHORE) PTHA

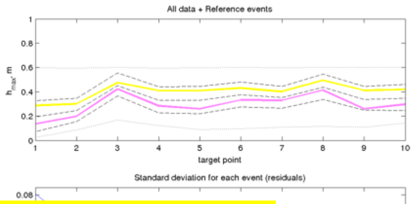




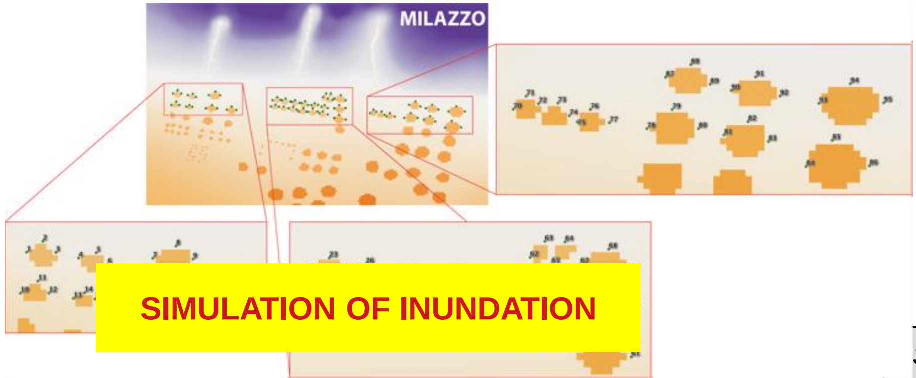


LOCAL HAZARD





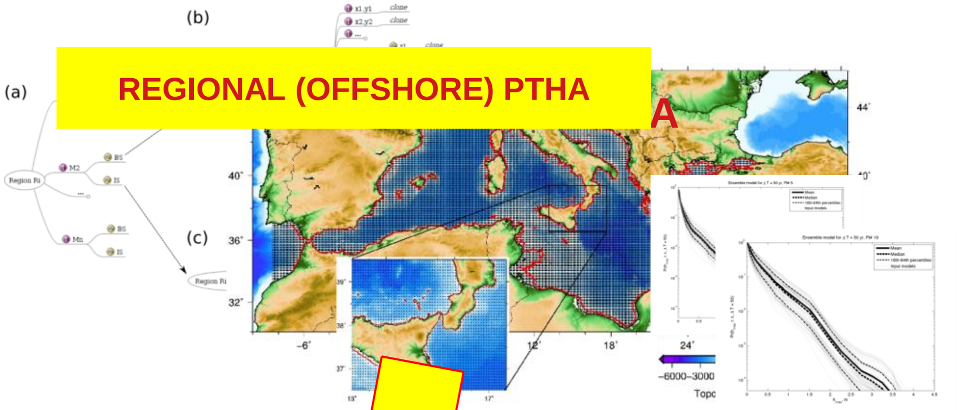
EXTRACTION OF SCENARIOS (10^7) OFFSHORE THE TARGET POINT & DEFINITION OF REPRESENTATIVE SCENARIOS (10^3)



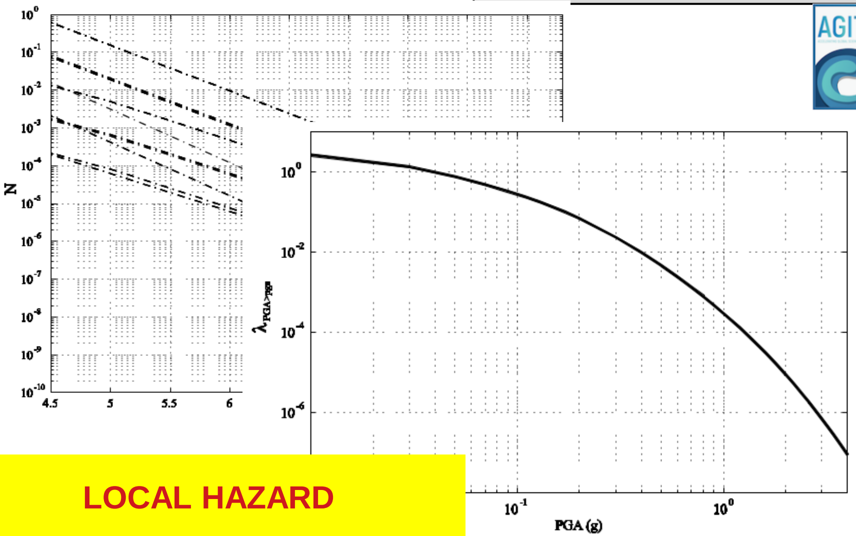
SIMULATION OF INUNDATION

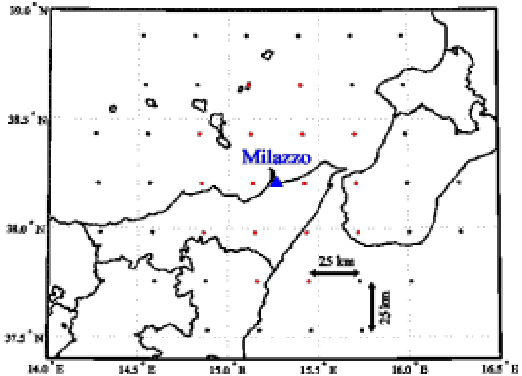
3. FROM SINGLE TO MULTI-HAZARD RISK

REGIONAL (OFFSHORE) PTHA



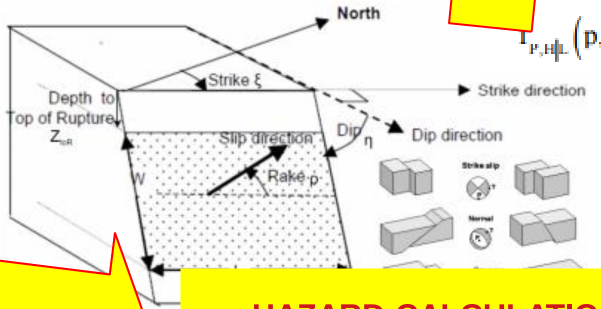
LOCAL HAZARD

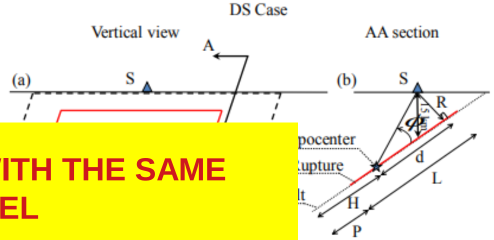




EXTRACTION OF LOCAL SOURCES FOR PSHA (subset of PTHA)

$$\lambda_{S_a>s_a} = \nu \cdot \int_m \int_l \int_p \int_h \int_{x_r} P\left[S_a > s_a \middle| m,l,p,x_r\right] \times f_{P,H|L}(p,h|l) \cdot f_{X_r|L}(x_r|l) \cdot f_{L|M}(l|m) \cdot f_M(m) \cdot dm \cdot dl \cdot dp \cdot dh \cdot dx_r$$





HAZARD CALCULATION WITH THE SAME SOURCE MODEL

3. FROM SINGLE TO MULTI-HAZARD RISK

COMMON FRAMEWORK FOR RISK QUANTIFICATION

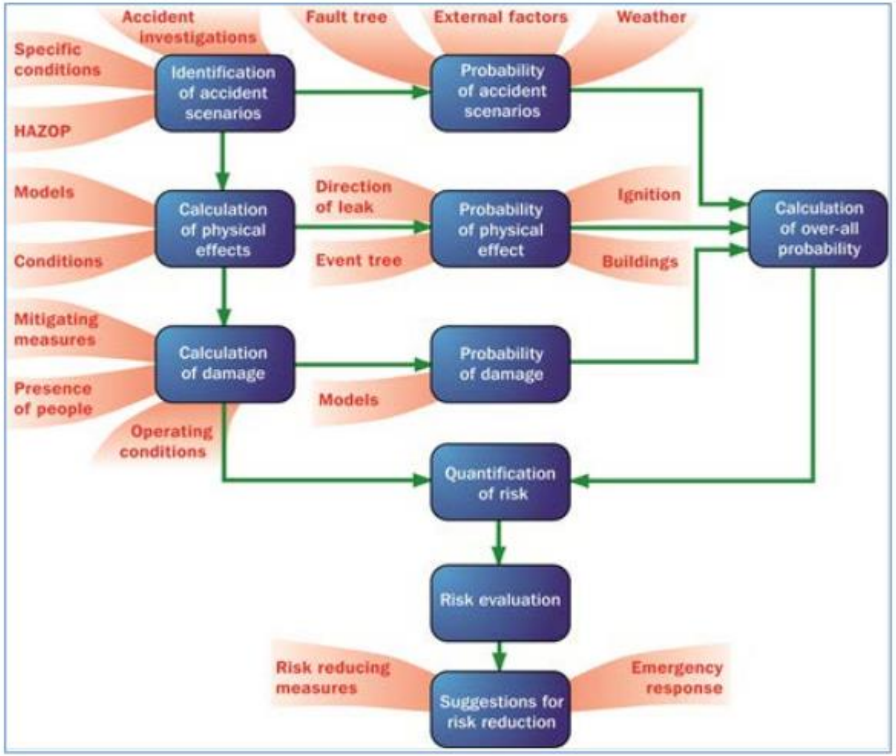
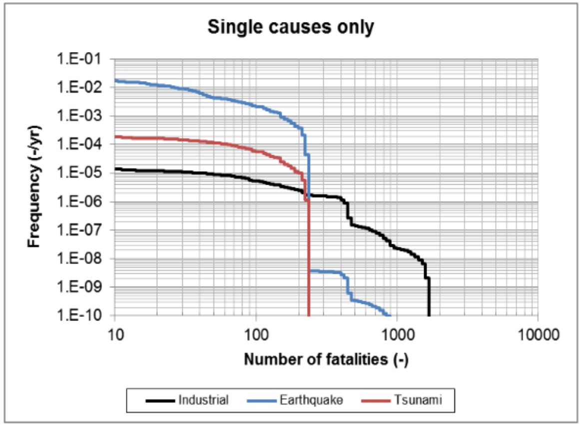
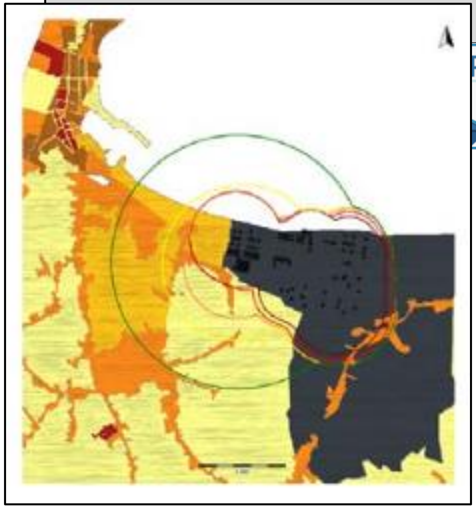
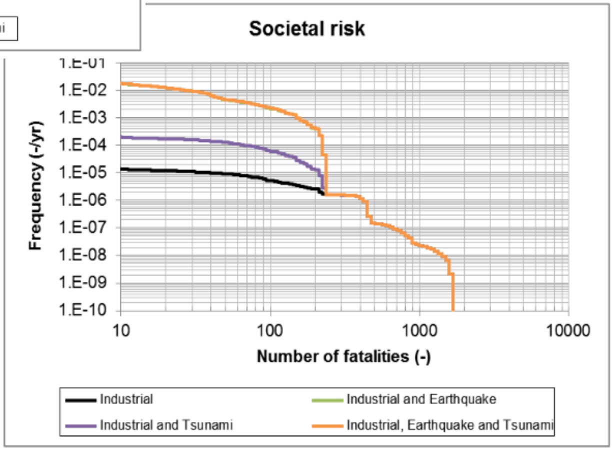


Fig. 2.14 Steps in a QRA and most important parameters







- ***Coherent single-risk quantification***
- ***First order multi-hazard risk** (no combined fragility curves)*

FOCUS POINTS

1) From regional to local PTHA

2) From single components to systemic vulnerability and risk of complex systems

3) From single to multi-hazard risk quantification

4) From single expert to multiple-experts for managing subjective choices

MULTIPLE EXPERTS TO MANAGE SUBJECTIVITY

NUREG/CR–6372
UCRL–ID–122160
Vol. 1

Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts

Main Report

Manuscript Completed: April 1997
Date Published: April 1997

Prepared by
Senior Seismic Hazard Analysis Committee (SSHAC)
R. J. Budnitz (Chairman), G. Apostolakis, D. M. Boore, L. S. Cluff, K. J. Coppersmith, C. A. Cornell, P. A. Morris

Electric Power Research Institute (EPRI)
ound in attempting to characterize
J.S. east of the Rocky Mountains. Most
ports for most sites in the eastern U.S.
differed significantly. However, the median hazard results did not differ by nearly as much. We now understand that differences in both the inputs and the procedures by which the two studies dealt with the inputs were among the key reasons for the differences in the mean curves. At the time this was not understood, and the differences between the mean curves caused not only considerable consternation, but launched several efforts to understand what might underlie the differences and attempts to update the older work.

Ultimately, the inability to understand all of the differences between the LLNL and EPRI hazard results—

MULTIPLE EXPERTS TO MANAGE SUBJECTIVITY

NUREG/CR–6372
UCRL–ID–122160

ISSUE DEGREE	DECISION FACTORS	STUDY LEVEL
A Non-controversial; and/or insignificant to hazard		**1** TI evaluates/weights models based on literature review and experience; estimates community distribution
B Significant uncertainty and diversity; controversial; and complex	•Regulatory concern •Resources available •Public perception	**2** TI interacts with proponents & resource experts to identify issues and interpretations; estimates community distribution
C Highly contentious; significant to hazard; and highly complex		**3** TI brings together proponents & resource experts for debate and interaction; TI focuses debate and evaluates alternative interpretations estimates community distribution
		4 TFI organizes panel of experts to interpret and evaluate; focuses discussions; avoids inappropriate behavior on part of evaluators; draws picture of evaluators' estimate of the community's composite distribution; has ultimate responsibility for project

MULTIPLE EXPERTS TO MANAGE SUBJECTIVITY

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Needs of TSUMAPS

- Development of alternative scientifically acceptable choices (to represent the variability within the technical community)
- Weight the alternatives, as input to the ensemble
- We have to manage subjective choices to obtain robust results

Solution

- Specific protocol to manage subjectivity to quantify the community distribution (in TSUMAPS: alternatives + weights)

→ *Trackable decision making, forcing to use up-to-date method & expose limitations*

Multiple-expert integration process for managing epistemic uncertainty

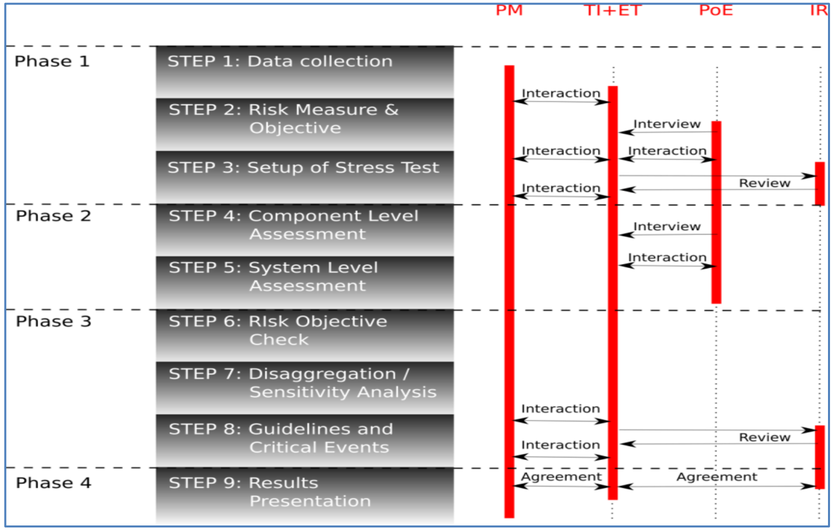
Goal: rational management of critical choices and consequent epistemic uncertianty, to increase credibility, stability and robustness of results.

→ *similar to SSHAC Levels 2/3, with important differences (classical elicitations, extension to multi-hazard/risk,…)*

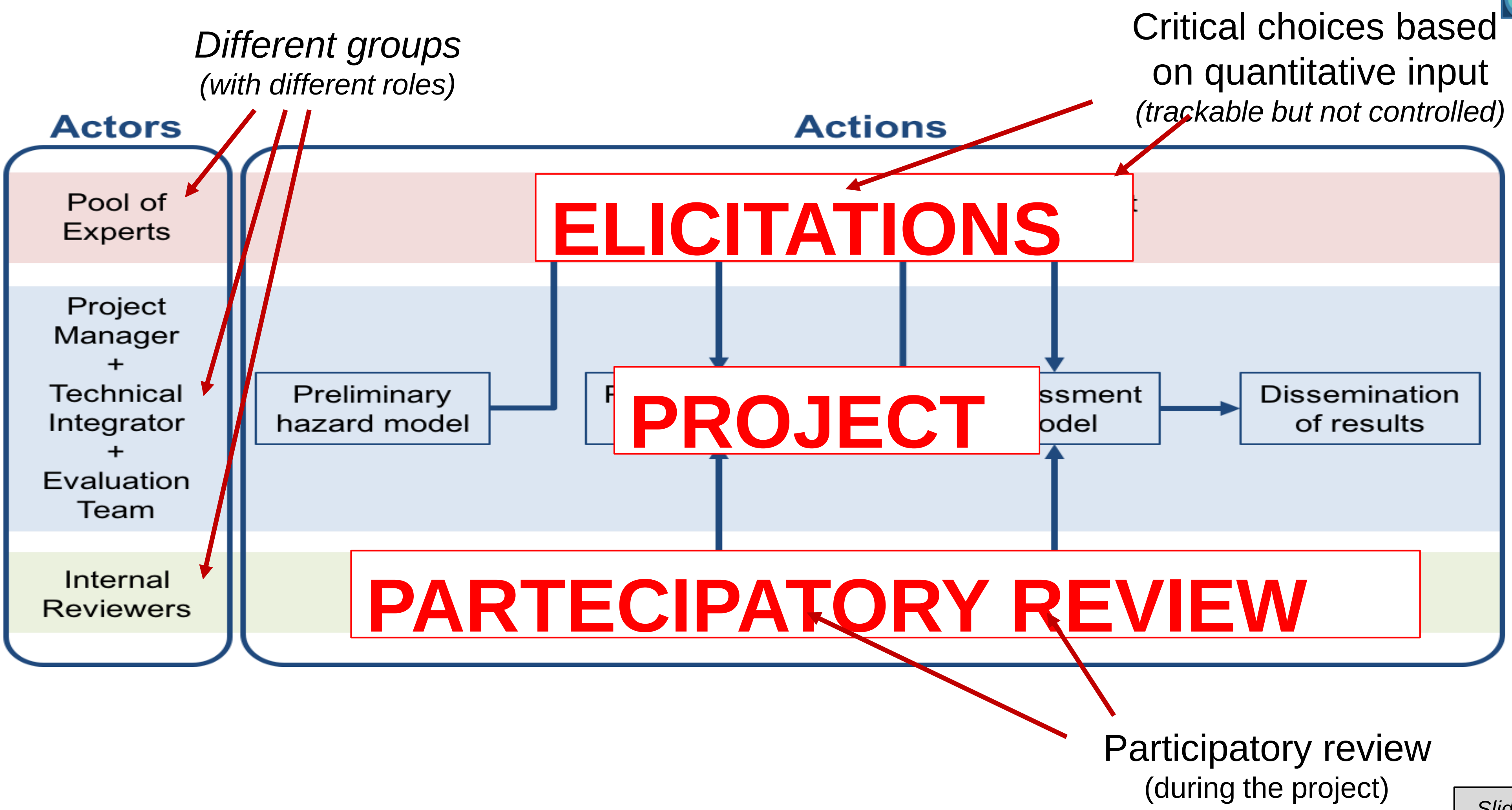
Actors: Project Manager (PM), Technical Integrator (TI), Evaluation Team (ET), Internal Reviewers (IR), Pool of Experts (PoE).

Key features:

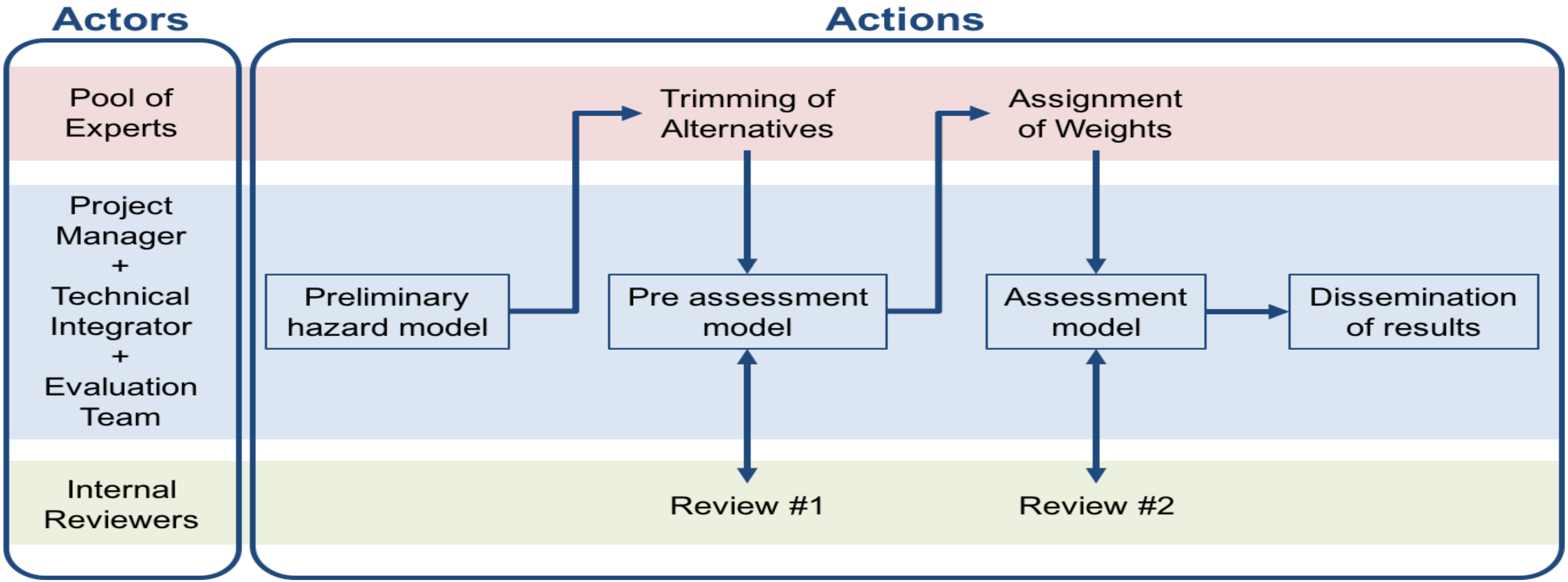
- Definition of roles, transparency & accountability, independence
- Scalability and flexibility (depending on the complexity)
- Extensive use of structured Expert Elicitation
- Adaptable to hazard, risk, multi-hazard/risk



MULTIPLE EXPERTS TO MANAGE SUBJECTIVITY



MULTIPLE EXPERTS TO MANAGE SUBJECTIVITY



CONCLUSIONS

- STREST developed a **stress test framework** based on PRA

- Stress test **levels increase in complexity**:
  → from single component to system level analyses
  → from single to multi-hazard risk quantification
  → from single to multiple expert involvement to constrain epistemic uncertainty

- Within STREST, we developed:
  → A procedure to produce **local PTHA** based on inundation simulation
  → A "protocol" to manage subjectivity based on **multiple-expert participation**