UNIVERSITY OF BERGEN

AGITHAR «cookbook» on Probabilistic Tsunami Hazard and Risk Assessment (PTHA/PTRA)

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AGITHAR main objectives

- **Assess current approaches** in tsunami hazard and risk assessment, and evaluate them quantitatively by means of common metrics and benchmarks;
- **Determine gaps** in scientific knowledge, methodological approaches and tools in order to achieve robust tsunami hazard and risk assessment across a variety of tsunami sources, including earthquakes, landslides, volcanoes, and meteorological events;
- Derive and agree on **best practices and standards** for probabilistic tsunami hazard and risk assessment, through discussion by a large group of practitioners;
- Identify issues and challenges to **orient future research**;
- **Disseminate** the acquired knowledge among hazard and risk practitioners and end-users.

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Why a cookbook?

- PTHA/PTRA is relatively new and developing fast
- PTHA/PTRA is characterized by several workflows, more complex than seismic analogies
- Still a need to establish best practices for PTHA/PTRA to
  - Support scientists working in the field
  - Improve reliability of studies applying such methods

Cookbook format allows us to

- Present the different “ingredients” individually, and then present various ways of combining the ingredients into a “recipe” that will lead to a meaningful hazard or risk assessment.
- Give overview of existing methods
- Unify the descriptions of workflows
- Make best practices examples available to the community
- Provide background information to stakeholders

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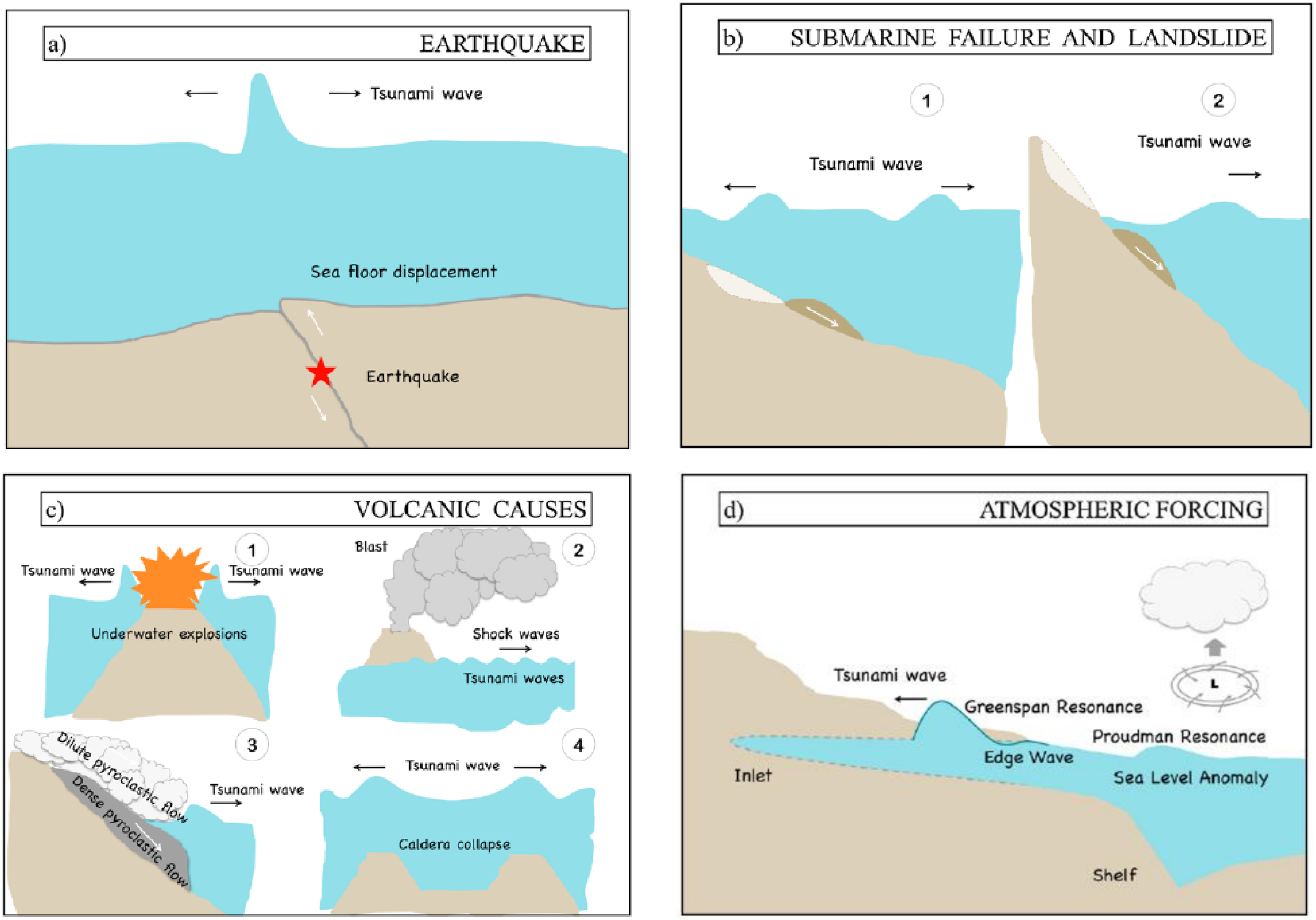
The work process

- Structure and ToC developed during AGITHAR meetings (Malaga, June 22 and Prague, Sep 22)
- Writing groups w. chapter responsible for each chapter/recipe
- 8 editors contribute, support and review
- Planned submission spring 2024 w. open access publication late 2024

Tsunami sources



Grezio et al., 2017

Main steps/elements of PTHA/PTRA

2. Frameworks

Framework:
Deterministic or probabilistic
Propagation of uncertainties

Consider:
Intended use of results
Spatial scale
Available data
Computational resources
Human resources

3. Source selection

Source paramterization:
What sources
Location and size

Consider:
Selected framework
Available data
Spatial scale

Source activity rates:
Representation of activity rates
Selection of scenarios

Consider:
Selected framework
Available data

4. Source modelling

Source dynamics:
Modeling of source process

Consider:
Available data
Computational resources

5. Hydrodynamic modelling

Tsunami initiation:
Boundary conditions
Mapping source process into water disturbance

Consider:
Source dynamics
Choice of propagation model
Computational resources

Tsunami propagation:
Propagation from source to coast

Consider:
Available data
Computational resources
Extent of domain (global/regional)

Tsunami inundation:
Inundation
Interaction with land masses

Consider:
Intended use of results
Available data
Computational resources

→ PTHA ↓

6. Exposure

Tsunami exposure:
Choice of assets
Resolution

Consider:
Intended use of results
Available data

7. Vulnerability

Tsunami vulnerability:
Physical and/or social vulnerability
Approach for vulnerability assessment

Consider:
Intended use of results
Available data

→ PTRA →

8. Risk communication

Risk communication:
Design of communication process

Consider:
Intended use of results
Target audience
Human resources

Cookbook structure

Part 1: Ingredients

- Introduction (*Sørensen et al.*)
- Frameworks in tsunami hazard and risk assessment (*Zamora et al.*)
- Source selection and their activity rates (*Løvholt et al.*)
- Source modelling (*Løvholt et al.*)
- Hydrodynamic modelling (*Behrens et al.*)
- Exposure modelling (*Salgado-Gálvez et al.*)
- Vulnerability modelling (*Baiguera et al.*)
- Communicating tsunami risk and uncertainties (*Kalligeris et al.*)
- Final remarks (*Behrens et al.*)

Part 2: Recipes

- 25 recipes describing implementations of PTHA or PTRA workflows

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Frameworks for tsunami hazard and risk assessment (Ch. 2)

FW1: Probabilistic tsunami risk assessment

- **FW1A**: Fully simulation-based risk assessment
- **FW1B**: Simulation-based hazard convolved with vulnerability and loss using numerical integration
- **FW1C**: Incorporation of dynamic processes with time dependency: tidal and sea level variations
- **FW1D**: Working on a limited number of scenarios

FW2: Tsunami risk assessment with special focus on indicator-based vulnerability assessment

- **FW2A**: Indicator-based physical vulnerability assessment
- **FW2B**: Indicator-based social (or multi-dimensional) vulnerability assessment

Tsunami data and observations in PTHA

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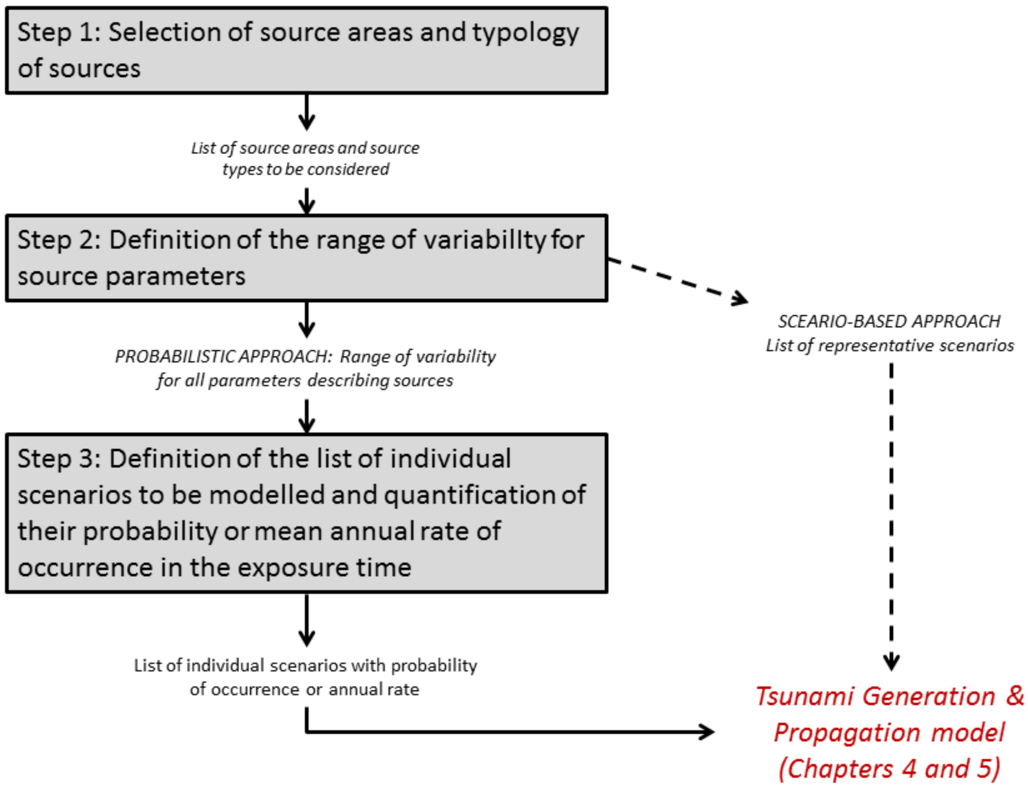
Source selection and their activity rates (Ch. 3)

Three steps for each of the four source types



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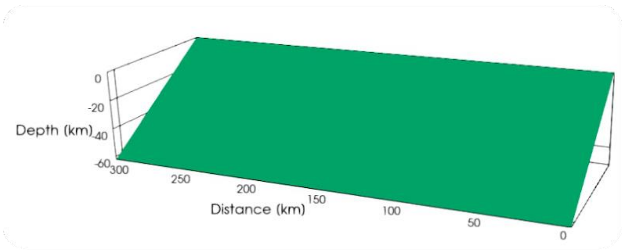
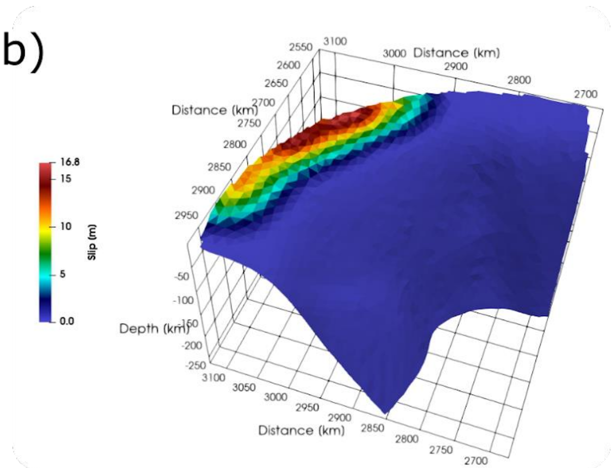
Source modelling (Ch. 4)

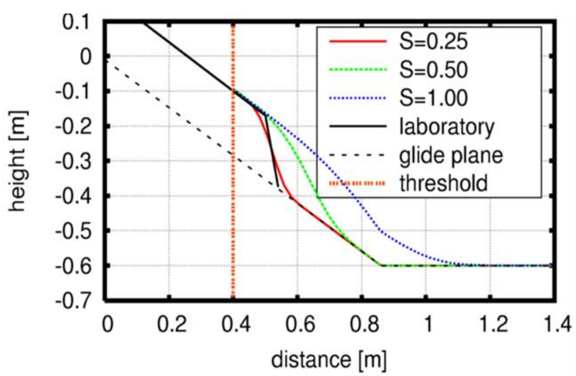
a)

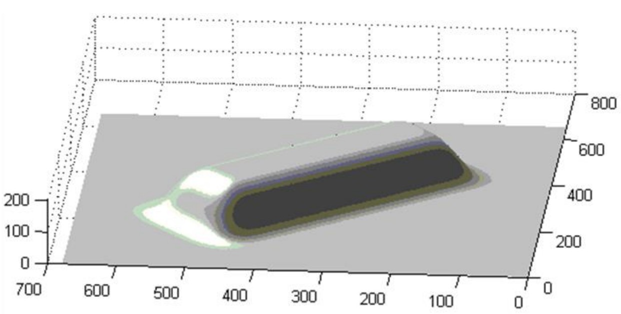


b)



How can we numerically represent the source (top – subduction zone EQ) and tsunami initiation (bottom – submarine landslide)





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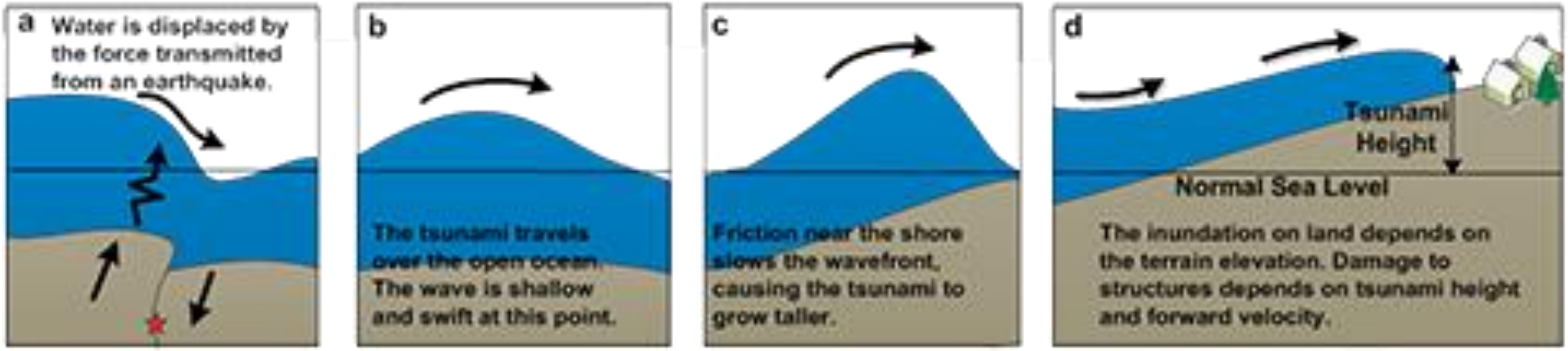
Hydrodynamic modelling (Ch. 5)



www.air-worldwide.com

Initiation – Propagation – Shoaling - Inundation

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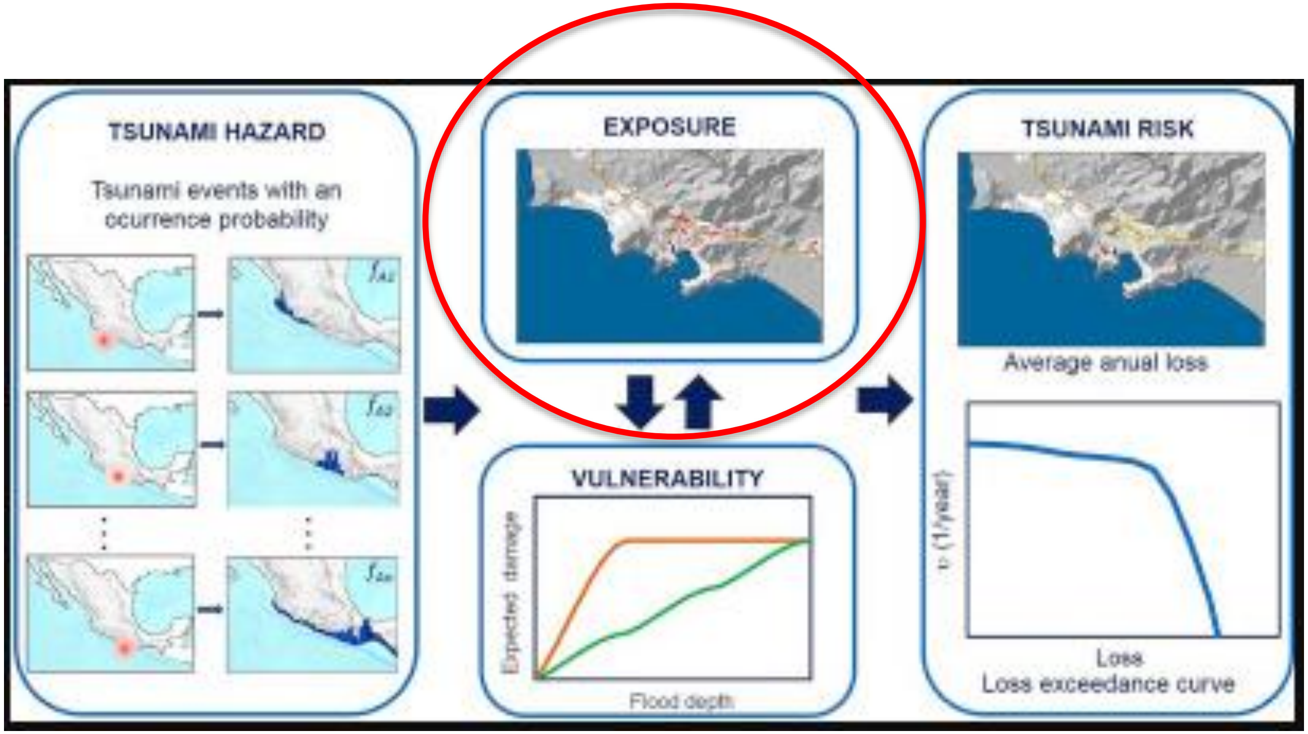
Exposure modelling (Ch. 6)



Human exposure – built environment - assets

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Vulnerability modelling (Ch. 7)

Tsunami Risk = Hazard * **Vulnerability** * Exposure

Tsunami Risk	Hazard	Vulnerability	Exposure
Rate of exceeding different levels of **tsunami losses** (monetary/ human/…)	Rate of exceeding different measures of **tsunami intensity** (e.g. inundation depth)	**Expected loss** in different types of buildings given different levels of intensity measure	Proportions and total quantities of **different building types** in inventory (study area)

Empirical – Analytical – Indicator based vulnerability

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Communicating tsunami risk and uncertainties (Ch. 8)

Figure 2

Advice to scientists on tsunami risk communication with and to different audiences

Figure 2

Figure 3

Figure 4

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The «recipes»

25 recipes covering the different aspects of PTHA and PTRA

Developed with a similar structure for all recipes for to allow reader to quickly get an overview and find specific information.

The NEAM Tsunami Hazard Model 2018 (NEAMTHM18) - Region-wide probabilistic tsunami hazard based on a large number of tsunami scenarios

Roberto Basili, Stefano Lorito (INGV)

Introduction

The purpose of this study was to provide the first homogeneous region-wid
Probab
North E
ground
maps f
2017. T
release
The ha
that is,

Surrogate-based PTHA

Cléa Denamiel, Dimitra Salmanidou

Introduction

del approaches – providing fast-running approximation of
e been gaining traction in the geoscience community (e.g.,
al., 2016; Sraj et al., 2014; Giraldi et al., 2017). Compared
Monte Carlo simulations), surrogate models are highly
ation, and, once trained, can be used without additional
e Maître, 2006; Najm et al., 2009). Further, as surrogate
needs and as their training is relatively cheap, they require
tional resources.

Bayesian Empirical Fragility Assessment for Hierarchical Damage Levels (Sulawesi-Palu)

Authors: Fatemeh Jalayer (UCL), Hossein Ebrahimian (UNINA)

Introduction

This recipe aims to describe a procedure for empirical tsu
hierarchical damage levels using generalized linear regression b
model class selection (BMCS). Although developed and descri
quite general for various types of hazards as long as they ca
measure. This procedure is primarily used for fragility assessme
also for vulnerability assessment for hierarchical fatality and los
versatility and utility of this recipe beyond the specific use cas
fragility assessment based on observed damage data from Sulav

Combination of multiple tsunami rate estimates weighted by uncertainty with likelihood functions: An example runup probability map for the Caribbean region

Tom Parsons and Eric L. Geist, U.S. Geological Survey, Moffett Field, CA, USA

Introduction

The purpose of this exercise is to develop methods for combining multiple tsunami rate

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The recipes

Nr	Title	Authors
1	The NEAM Tsunami Hazard Model 2018 (NEAMTHM18) - Region-wide probabilistic tsunami hazard based on a large number of tsunami scenarios	Basili, Lorito
2	Local Probabilistic Tsunami Hazard Analysis	Volpe, Gibbons, Baglione
3	PTHA in Meso and Macro Tidal Areas. Application to the Cádiz Bay, Spain	Aniel-Quiroga, González, Baptista, Macías
4	Event-tree PTHA of coastal inundation with tidal uncertainty treatment	Omira, Baptista, Matias
5	Combination of multiple tsunami rate estimates weighted by uncertainty with likelihood functions: An example runup probability map for the Caribbean region	Geist, Parsons
6	Worst-case tsunami approach applied to Catania (eastern Sicily)	Zaniboni, Armigliato
7	ASCETE Coupled Earthquake-Tsunami Modelling	Behrens
8	Probabilistic tsunami hazard analysis for landslide sources tsunami component – the Lyngen case	Løvholt
9	Probabilistic hazard analysis for tsunamis generated by subaqueous volcanic explosions in the Campi Flegrei caldera, Italy	Grezio, Paris, Selva
10	Adriatic A-PTH	Denamiel
11	Surrogate-based PTHA	Denamiel, Salmanidou
12	Multi-source (Bayesian) PTHA in the Gulf of Naples	Grezio, Selva
13	Global Risk Model 2015 - tsunami component - global risk and loss computation	Løvholt, Salgado-Gálvez, Davies
14	Event-based probabilistic earthquake and tsunami risk assessment – application in Acapulco (Mexico) and Callao (Peru)	Salgado-Gálvez, Ordaz, Huerta
15	Multi-hazard Risk Assessment for Earthquakes and Tsunamis	Goda, Risi
16	Bayesian Empirical Fragility Assessment for Hierarchical Damage Levels (Sulawesi-Palu)	Jalayer, Ebrahimian
17	Nonlinear Pushover Analysis for Tsunami	Baiguera, Zoppo, Rossetto
18	Analytical vulnerability curves for Italian buildings portfolio	Zoppo, Di Ludovico, Prota
19	Indicator-based method for the assessment of the physical vulnerability of buildings to tsunami	Papathoma-Köhle
20	Monte Carlo approach for tsunami economic impact estimation in a pseudo-probabilistic framework	González del Pino, Macías, Llorente, Paredes
21	GITEWS End-To-End Early Warning	Lauterjung, Spahn, Behrens
22	Probabilistic Tsunami Forecasting for tsunami warning	Lorito, Selva
23	Use of neural networks for tsunami arrival time and maximum height prediction	Rodríguez, Macías
24	PTHA-based tsunami inundation mapping in Italy	Tonini, Bucci, Di Manna
25	Microzoning tsunami hazard assessment applied to evacuation decision making	Zamora, Catalán, Gubler

Thank you for your attention!

For questions, please contact
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