Simulated Ground Motions for the San Francisco Bay Area

18-19 January 2024 | PEER – LBNL Workshop

IMPLICATIONS OF THE USE OF PHYSICS-BASED SIMULATIONS IN THE (RE)INSURANCE SECTOR

19.01.2024

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Introduction

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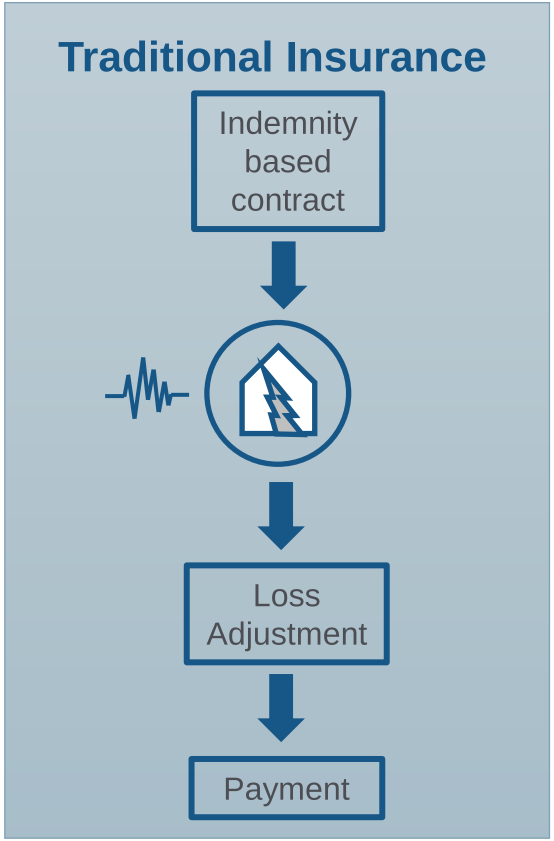

Introduction

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Traditional Insurance

"The non-life insurance pricing consists of establishing a premium or a tariff paid by the insured to the insurance company in exchange for the risk transfer. A usual way to obtain the insurance premium is to combine the conditional expectation of the claim frequency with the expected claim amount." (David, 2015)

Introduction

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Traditional Insurance

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"In reinsurance premiums are calculated very often by the so-called burning cost method (see Gerathewohl (1976), chapter 5), a very elementary estimating or forecasting method." (Kremer, 1984)

Introduction

Basic principle of insurance

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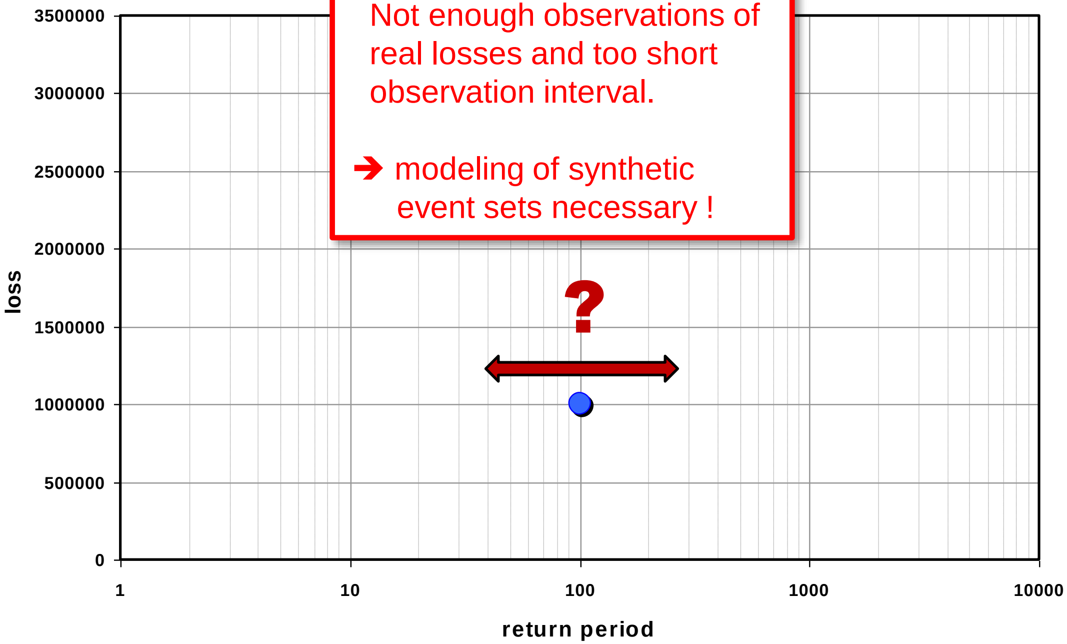
sum of premiums = **sum of loss**

(over a certain time) (over a certain time)



Problem:
Not enough observations of real losses and too short observation interval.

➔ modeling of synthetic event sets necessary !

Property Catastrophic Modelling

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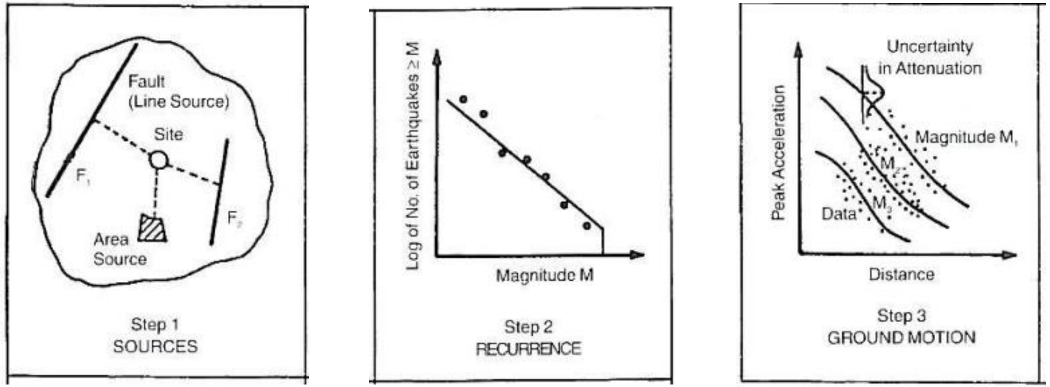

Modified by TERA, 1980

- **Probabilistic Seismic Hazard Assessment**, Cornell, 1968
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- **Monte Carlo simulation**, Musson, 2009

Property Catastrophic Modelling

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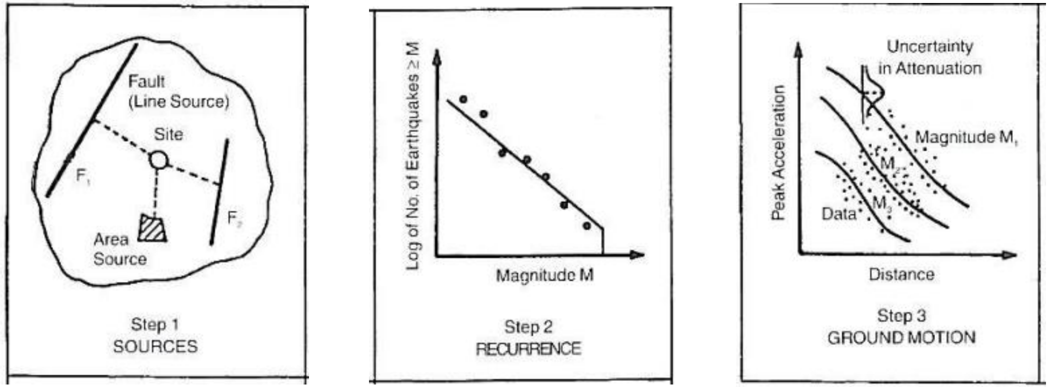

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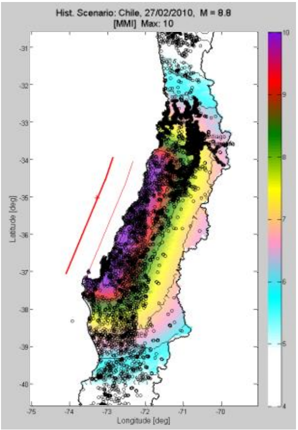

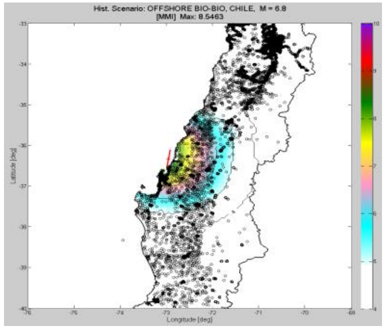

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  Musson, 2009

Property Catastrophic Modelling

Event Loss Table (ELT) and Annual Average Loss (AAL)

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Loss ID	Losses	Probability
71004490111	31880	0.0000250
71004500111	32900	0.0000202
71004510111	65890	0.0000178
71004520111	99899	0.0000157
71004530111	100918	0.0000138
71004540111	136489	0.0000122
71004550111	170498	0.0000108
71007540111	2504	0.0000122
71007550111	3589	0.0000108
71008490111	843	0.0000250
71008500111	1550	0.0000202
71008510111	1550	0.0000178
71008520111	2258	0.0000157
71008530111	4052	0.0000138
71008540111	5898	0.0000122
71008550111	7427	0.0000108
71011510111	1563	0.0000178
71011520111	1563	0.0000157
71011530111	3127	0.0000138
71011540111	4690	0.0000122
71011550111	4690	0.0000108
71012550111	1563	0.0000108
71014530111	18756	0.0000138
71014540111	37512	0.0000122
71014550111	61889	0.0000108
71015480111	9026	0.0000250
71015490111	10253	0.0000250
71015500111	14766	0.0000202
71015510111	20308	0.0000178
71015520111	25852	0.0000157
71015530111	26884	0.0000138
71015540111	38166	0.0000122
71015550111	50223	0.0000108
71016550111	1228	0.0000108
71017490111	620	0.0000250
71017500111	620	0.0000202
71017510111	1139	0.0000178
71017520111	1660	0.0000157
71017530111	1660	0.0000138
71017540111	3496	0.0000122
71017550111	4988	0.0000108
71018540111	620	0.0000122
71018550111	1139	0.0000108
71019500111	1526	0.0000202

⋮

Sort by losses

Annual average loss is computed via:

$$AAL = \sum_{i} (L_i * P_i)$$

Loss ID	Losses	Probability
79075601111	133998352	0.0000001
79074601111	129762193	0.0000001
79055601111	118293935	0.0000001
79073601111	117554340	0.0000001
79054601111	115358800	0.0000001
79035601111	105191113	0.0000001
79015601111	94939435	0.0000001
79072601111	94608504	0.0000001
79071601111	93994622	0.0000001
79053601111	90814195	0.0000001
79034601111	89545358	0.0000001
79019601111	88622112	0.0000001
79033601111	84867325	0.0000001
79052601111	84016389	0.0000001
79017601111	83749481	0.0000001
79018601111	82493940	0.0000001
79051601111	81582667	0.0000001
79069601111	81536053	0.0000001
79005601111	81495306	0.0000001
79070601111	81325784	0.0000001
79016601111	77205819	0.0000001
79002590111	77007852	0.0000002
79003590111	75319716	0.0000002
79020601111	75138043	0.0000001
79014601111	73726959	0.0000001
79021601111	72386374	0.0000001
79037601111	72107042	0.0000001
79006601111	72096580	0.0000001
79027601111	71831104	0.0000001
79025601111	71639091	0.0000001
79031601111	71213075	0.0000001
79038601111	70846538	0.0000001
79046601111	70825182	0.0000001
79007601111	70695378	0.0000001
79049601111	70616009	0.0000001
79050601111	70330444	0.0000001
79048601111	70320559	0.0000001
79008601111	69798792	0.0000001
79045601111	69680677	0.0000001
79068601111	69676089	0.0000001
79001590111	69618605	0.0000002
79028601111	69603323	0.0000001
79026601111	69529242	0.0000001

⋮

Cummulative sum over probabilities

Property Catastrophic Modelling

Probable Maximum Loss (PML)

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Traditional Insurance

Indemnity based contract

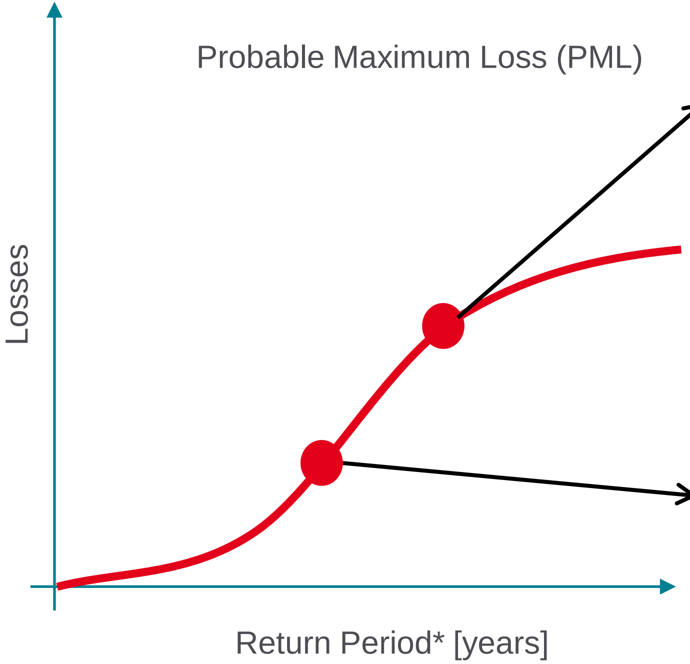
↓

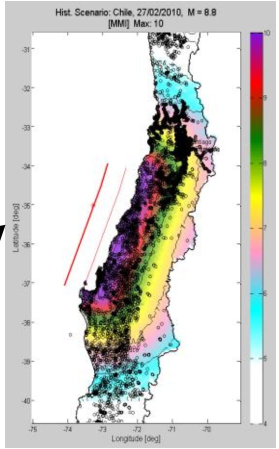
↓

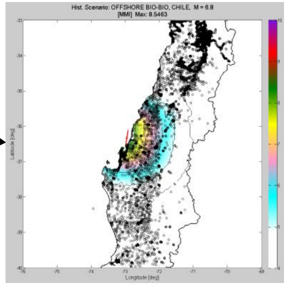
Loss Adjustment

↓

Payment







* = expected number of years between events that exceed a certain loss level (see also Homer&Li, 2017)

Property Catastrophic Modelling

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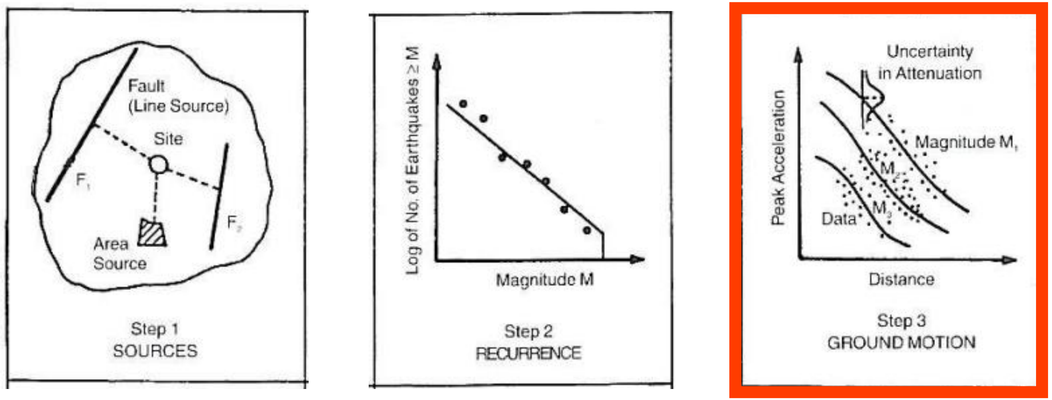

Modified by TERA, 1980

KEY WORDS:
(1) Ground Motion Models
(2) Portfolio
(3) Spatial Correlation

- **Probabilistic Seismic Hazard Assessment**, Cornell, 1968
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Ground Motion Models (GMMs)

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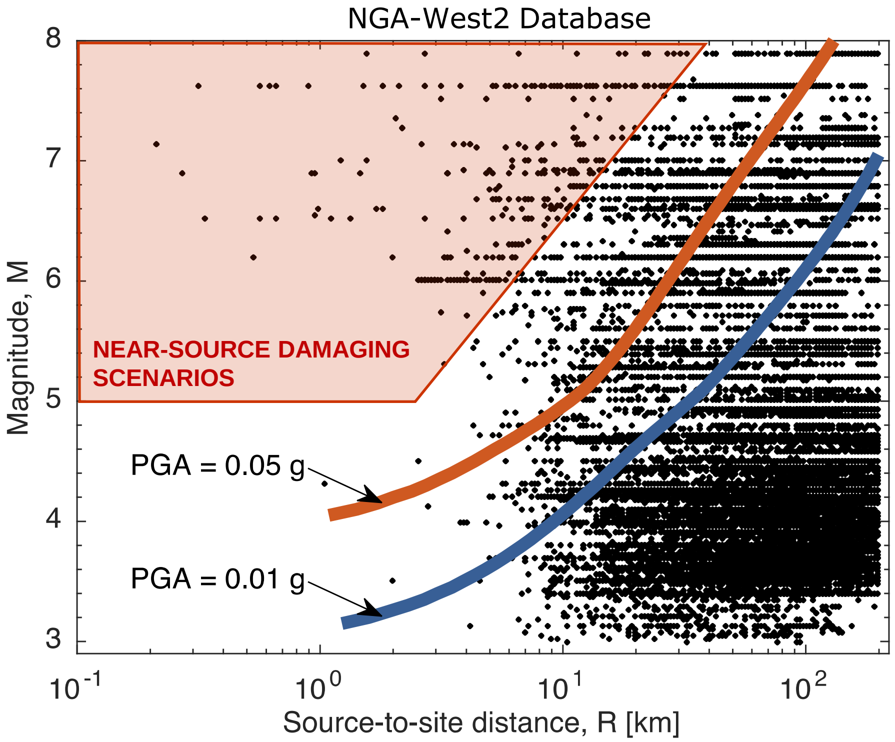
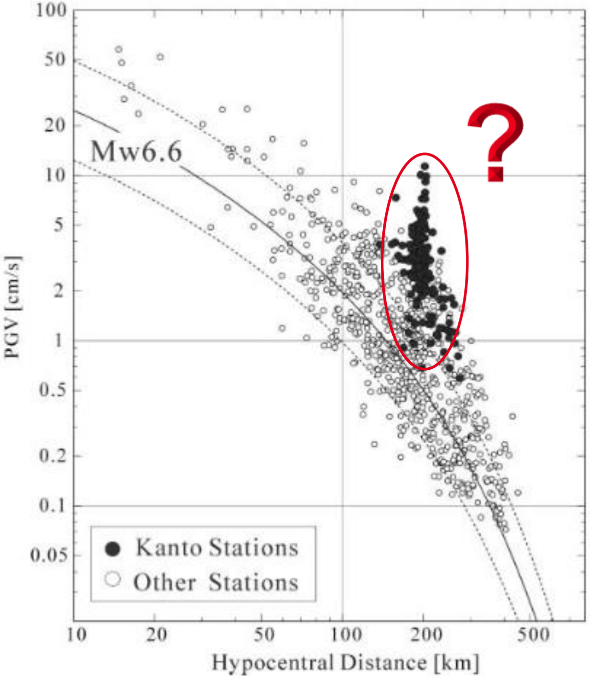


Baker, Bradley and Stafford (2021)



«Anomalous Propagation of Long-Period Ground Motions Recorded in Tokyo during the 23 October 2004 Mw 6.6 Niigata-ken Chuetsu, Japan, Earthquake» by Takashi Furumura and Toshihiko Hayakawa, Bulletin of the Seismological Society of America, Vol. 97, No. 3, pp. 863–880, June 2007, doi: 10.1785/0120060166

From a physical perspective the peculiar behavior of the records can be explained…

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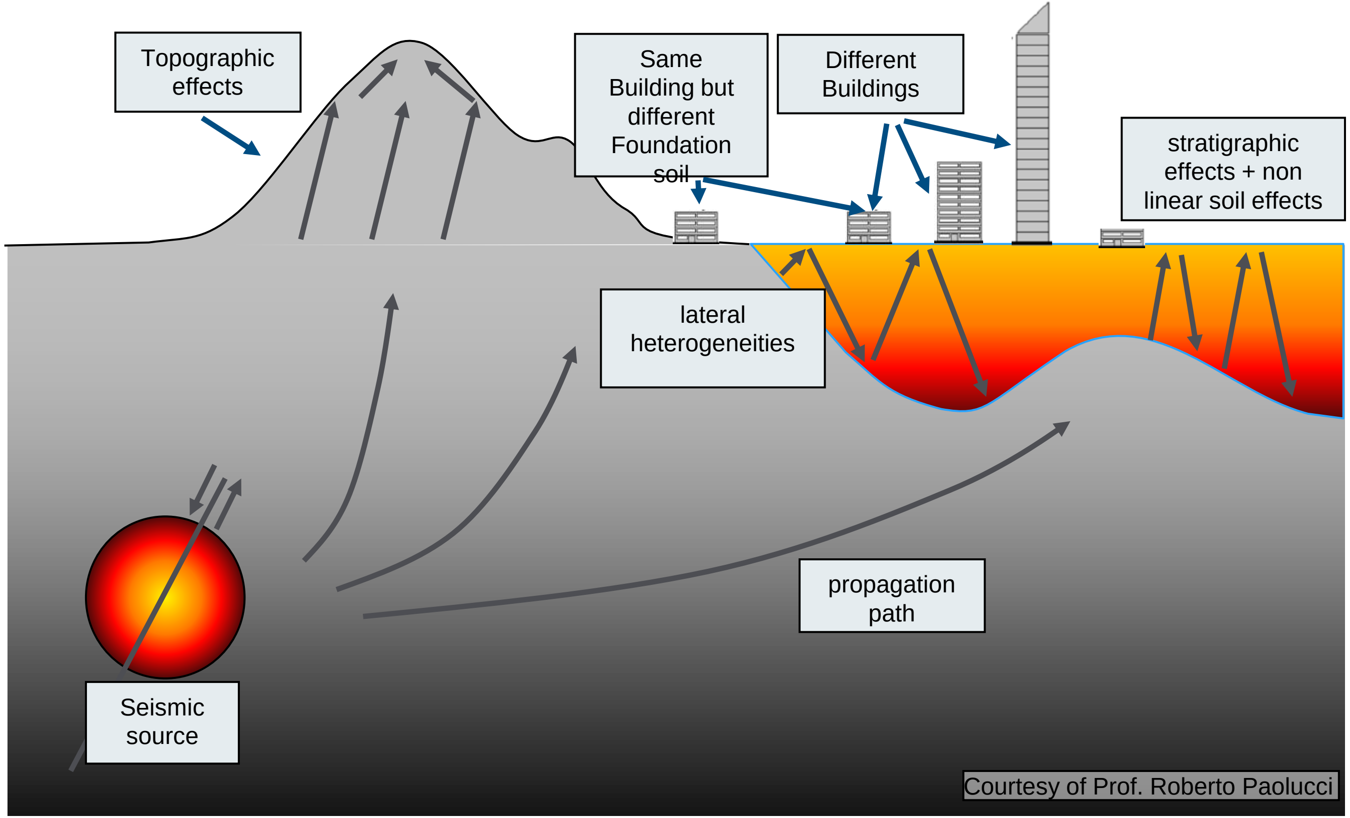

Physics-Based Scenarios (PBSs) need to be verified and validated

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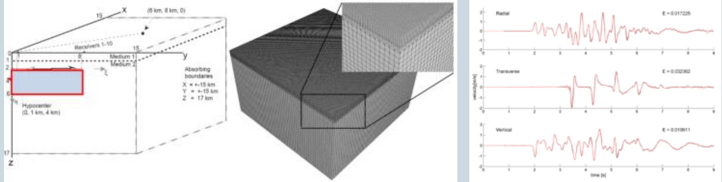
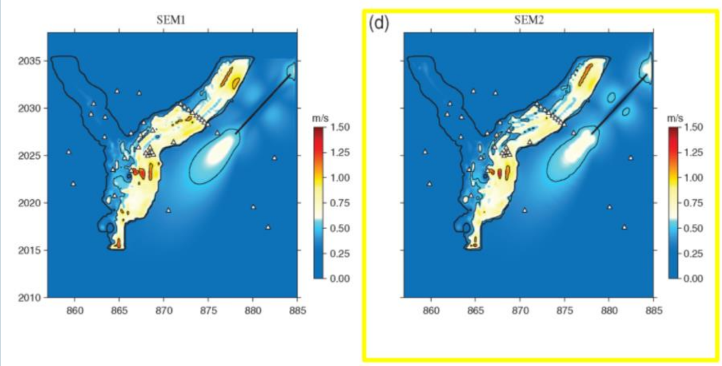
Verification

Stupazzini M, Paolucci R, Igel H (2009), *Near-fault earthquake ground-motion simulation in the Grenoble valley by a high-performance Spectral Element code*, BSSA , 99: 286–301.

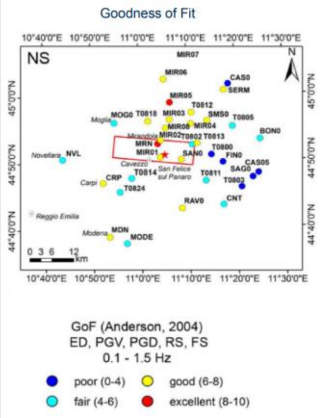


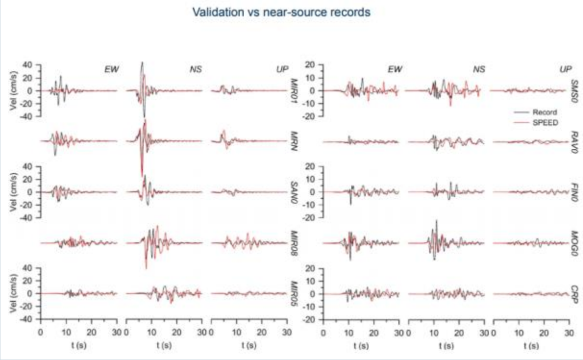
Chaljub E., Moczo P., Tsuno S., Bard P.Y., Kristek J., Käser M., Stupazzini M., Kristekova M. (2010), *Quantitative Comparison of Four Numerical Predictions of 3D Ground Motion in the Grenoble Valley, France*. BSSA, 100: 1427-1455



Validation

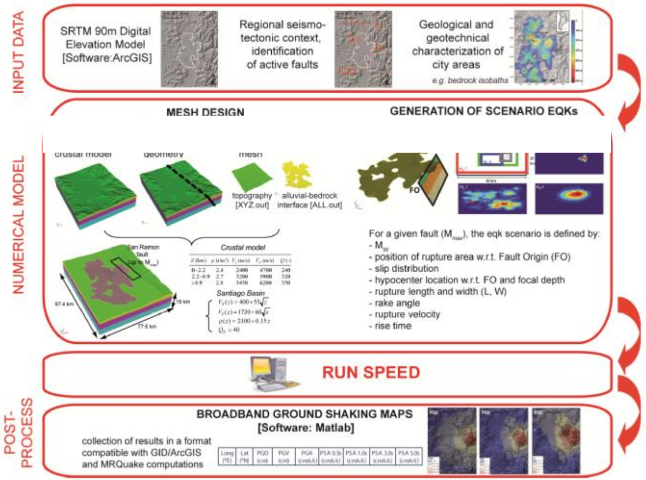
Paolucci R., Mazzieri I., Smerzini C., (2015), *Anatomy of strong ground motion: near-source records and three-dimensional physics-based numerical simulations of the Mw 6.0 2012 May 29 Po Plain earthquake, Italy, GJI*, 203-3: 2001–2020.

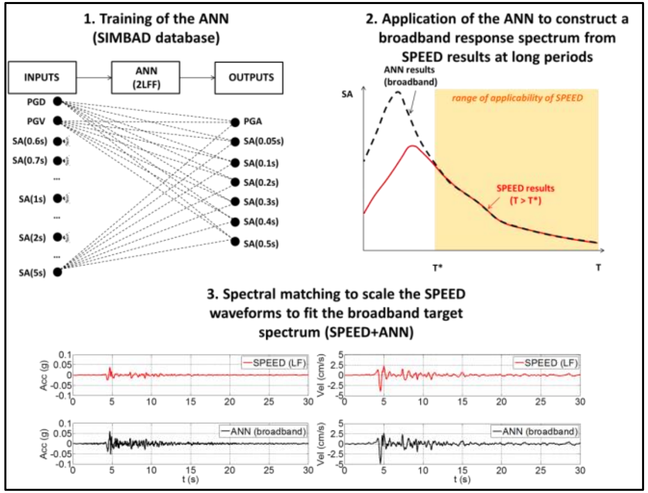




SPEED "recipe" to compute broadband (BB) ground motion simulations

step1, Physics-Based Scenario (PBS) + step2, Artificial Neural Network (ANN)





http://speed.mox.polimi.it/

R.Paolucci, F.Gatti, M.Infantino, C.Smerzini, A.Güney Özcebe, M.Stupazzini (2018), *Broadband Ground Motions from 3D Physics-Based Numerical Simulations Using Artificial Neural Networks*, BSSA, 108 (3A): 1272-1286.

OPINION PAPER

The Footprint of an Earthquake

George W. Housner, M.EERI

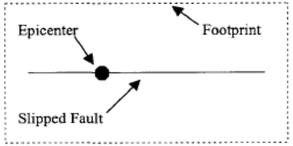
When the recent earthquake occurred in Turkey, it was generally known within a day where the epicenter was located and that the magnitude was M7.4. Many people asked me questions about the extent of damage and the loss of life that I could not answer because magnitude and epicenter do not provide sufficient information for engineers. For immediate engineering purposes one needs to know the approximate length, and the location and orientation of the fault slip (not the surface expression of the fault). The epicenter locates one point on the slipped length of fault, but this could be at either end or somewhere in the middle. In the case of the Turkey earthquake, the western end of the slipped length of fault seems to have been approximately 20 miles west of the epicenter, and the fault on which the slip occurred was essentially east-west trending. The locations of the ends of the slipped length of fault can usually be determined approximately by the clusters of aftershocks in their vicinities.

The length of slipped fault for an M7.4 earthquake would be about 60 miles, so the area subjected to strong shaking of 25% g or greater can thus be estimated to have had a length of about 70 miles and a width of about 40 miles, and this rectangle can be thought of as the strong motion footprint of the earthquake. The northwestern corner of the footprint was approximately 30 miles southeast of Istanbul, which explains why Istanbul was not more seriously damaged. Had the fault slip traveled farther west of the epicenter, the northern edge of the footprint would have passed 10 miles south of Istanbul, which would have caused much more damage. The foregoing discussion applies to strike-slip faults; other types of faults could have footprints of different shapes.

If, within a few days, the approximate location and dimensions of the footprint could be reported, it would be very helpful to outsiders in understanding the distribution of damage. The size of the footprint could be based on instrumental recordings and on insider observations of damage; and the width could be specified for 25% g or some lesser value as the situation requires. The slipped length L can be estimated from the Richter magnitude M, and if the location and orientation of the footprint can be estimated, many questions about damage and lack of damage could be answered. For a large earthquake the epicenter is not as helpful to engineers as is the footprint.

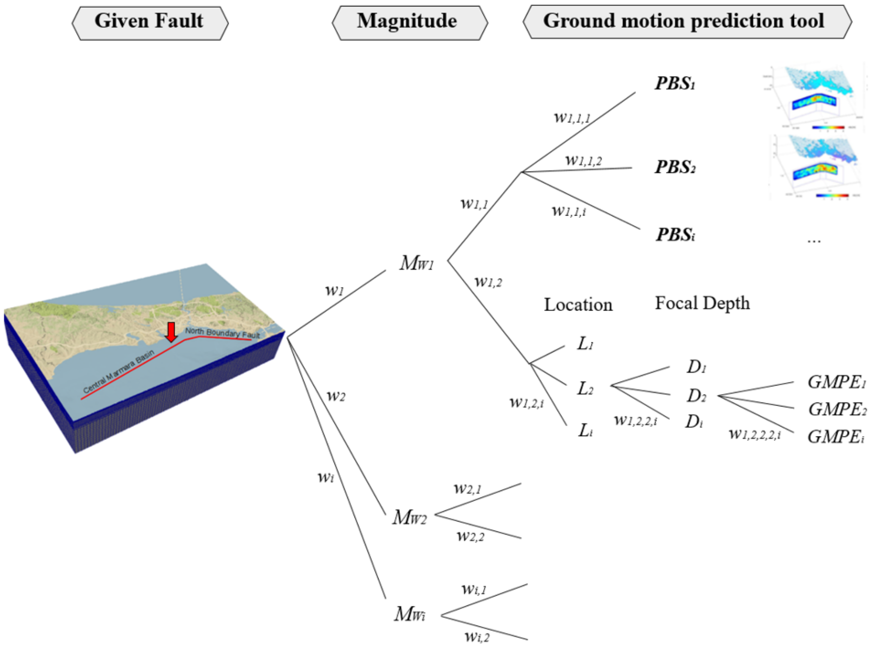
Approximate Locations

M	L
8.5	530
8.0	190
7.5	70
7.0	25
6.5	10



Department of Civil Engineering, California Institute of Technology, Pasadena, CA 91125

“Footprint” based PSHA



Stupazzini M., Infantino M., Allmann A., Paolucci R., 2020. „Physics based probabilistic seismic hazard and loss assessment in large urban areas: A simplified application to Istanbul“, Earthquake Engineering & Structural Dynamics 50(2), 99-115, DOI: 10.1002/eqe.3365

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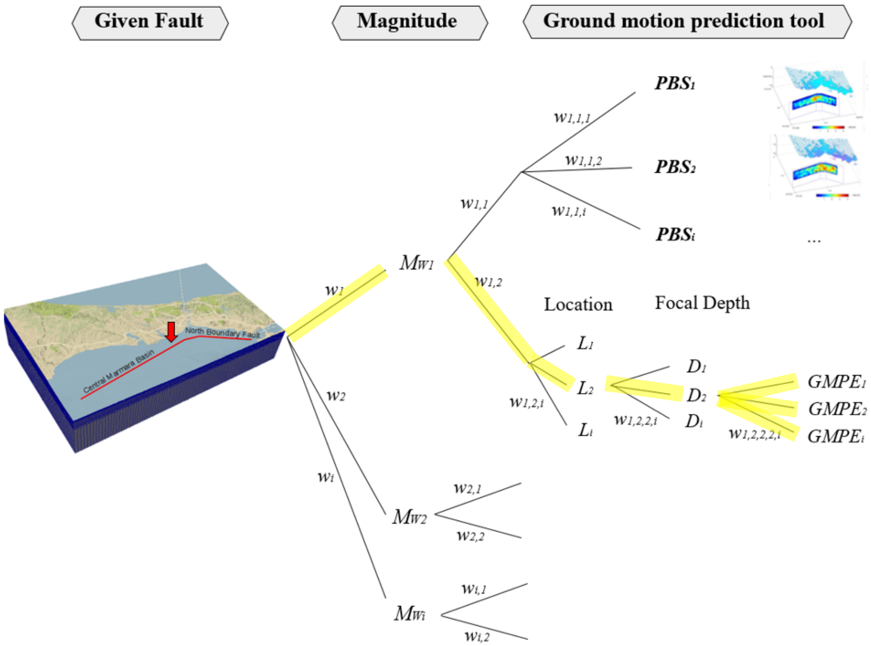

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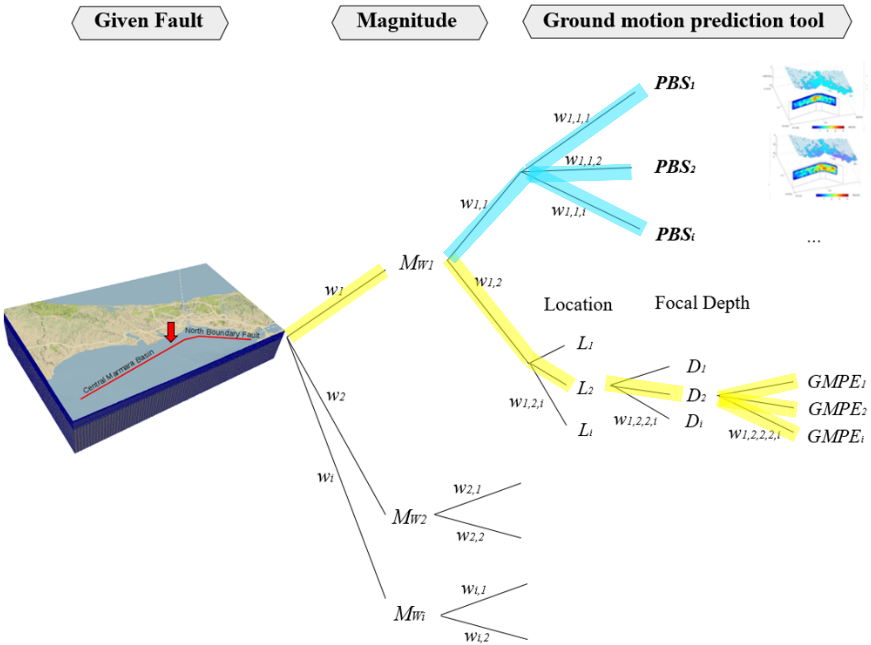

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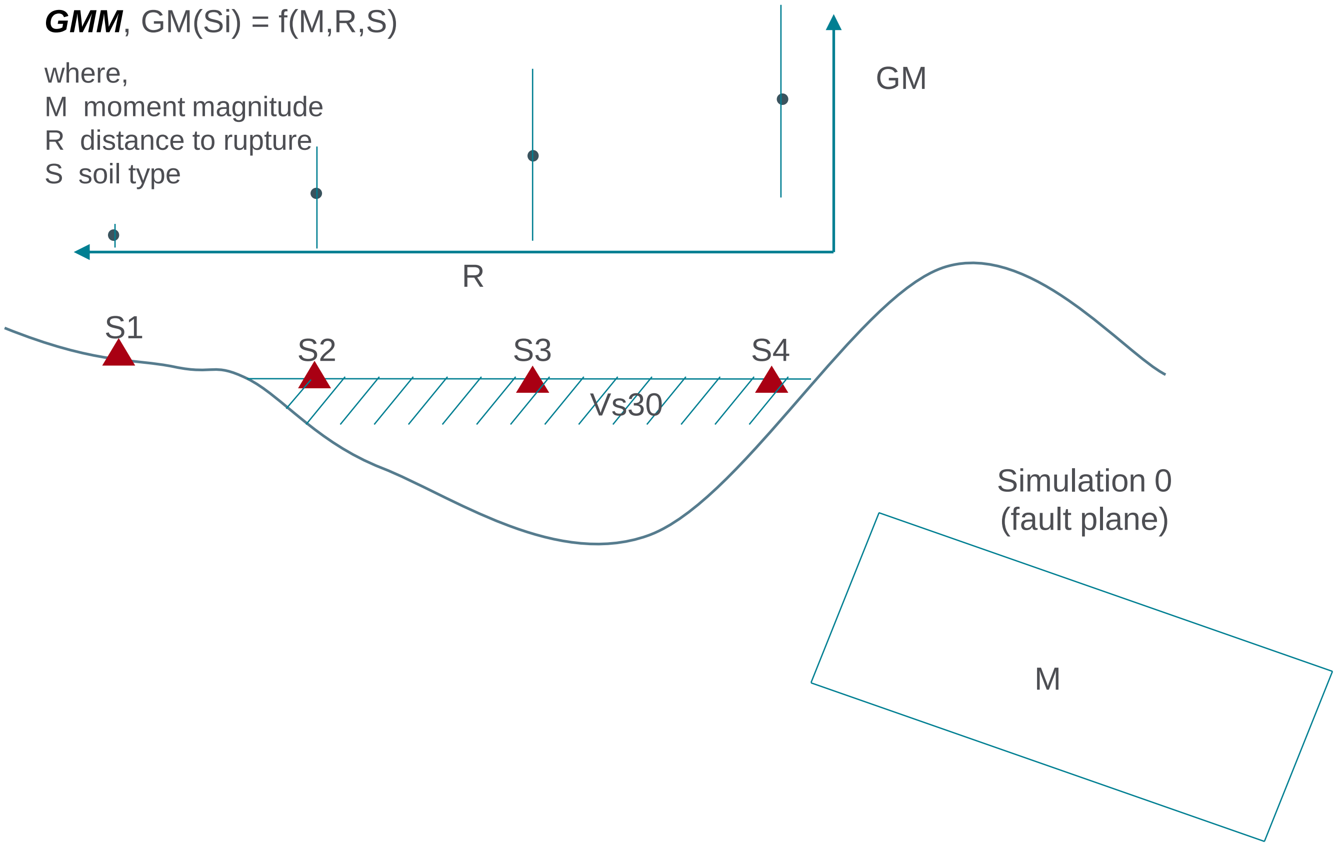
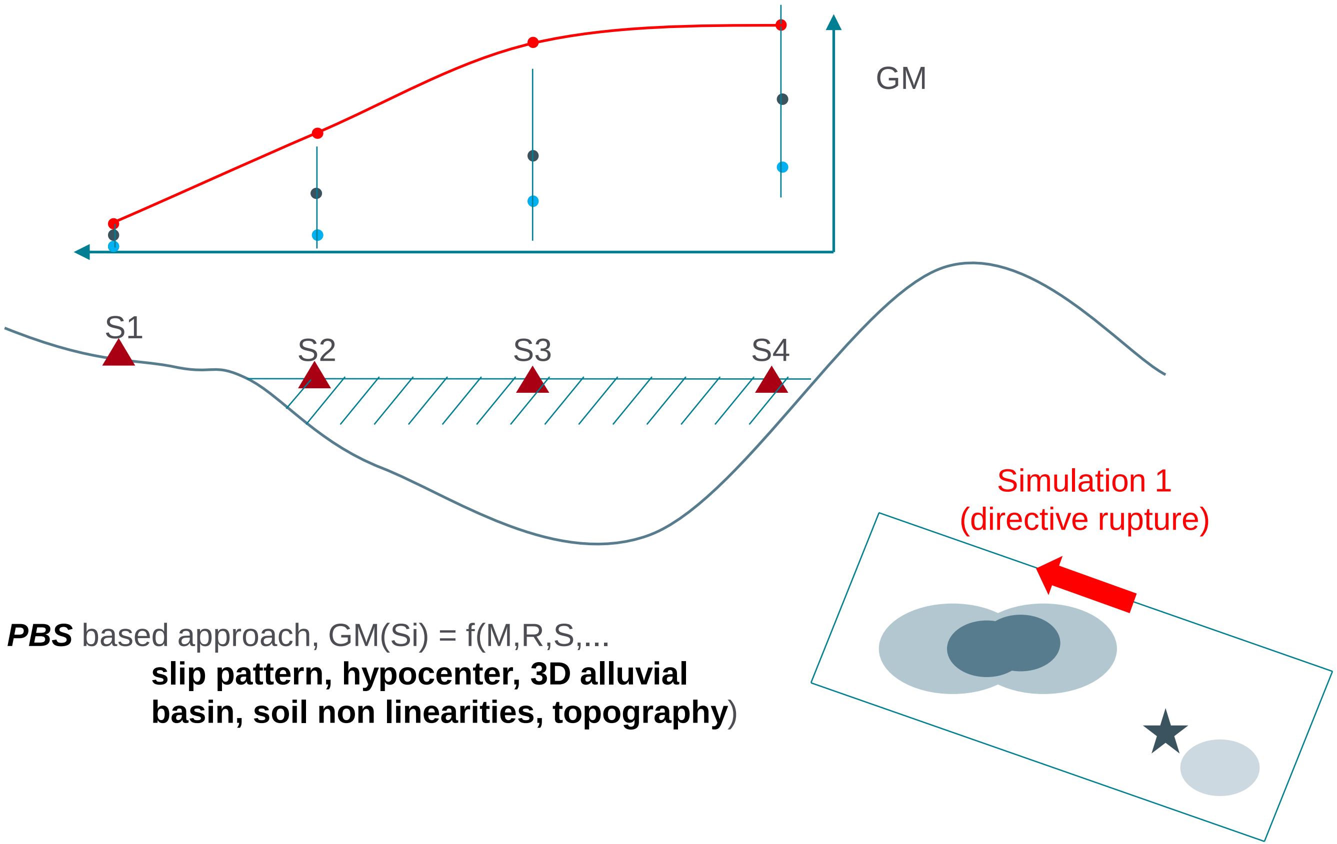
GMMs vs Physics-Based Scenario (PBS) in a nutshell

GMM, GM(Si) = f(M,R,S)

where,
M moment magnitude
R distance to rupture
S soil type

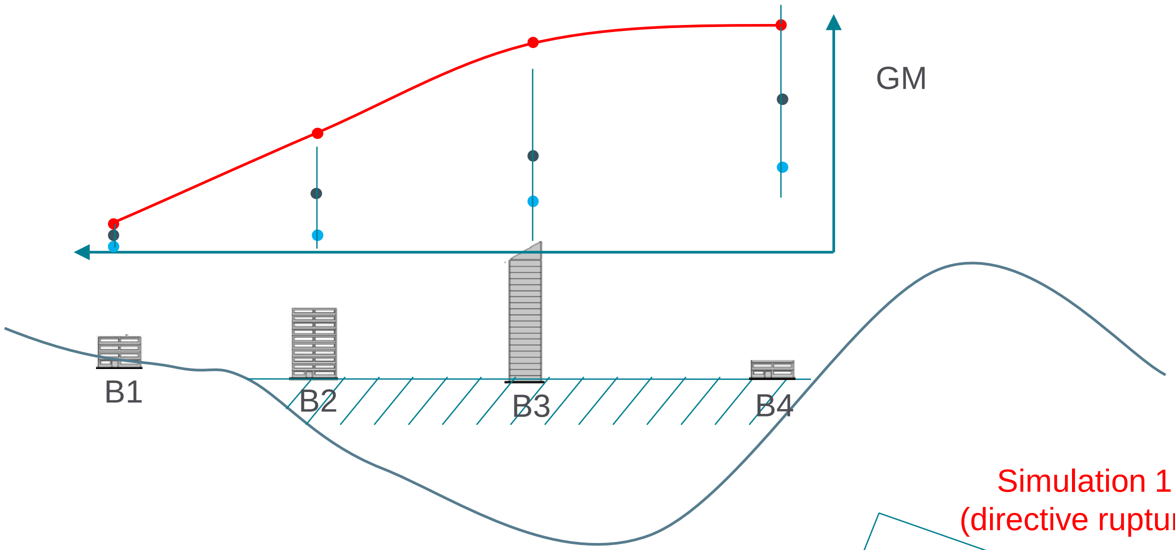


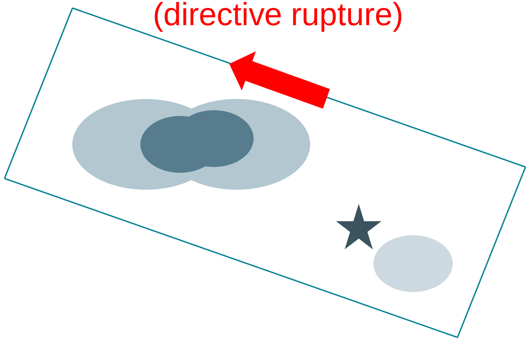
How to use PBS into SHA: “Footprint based” approach



PBS based approach, GM(Si) = f(M,R,S,...
slip pattern, hypocenter, 3D alluvial basin, soil non linearities, topography)

How to use PBS into PRA: “Footprint based” approach

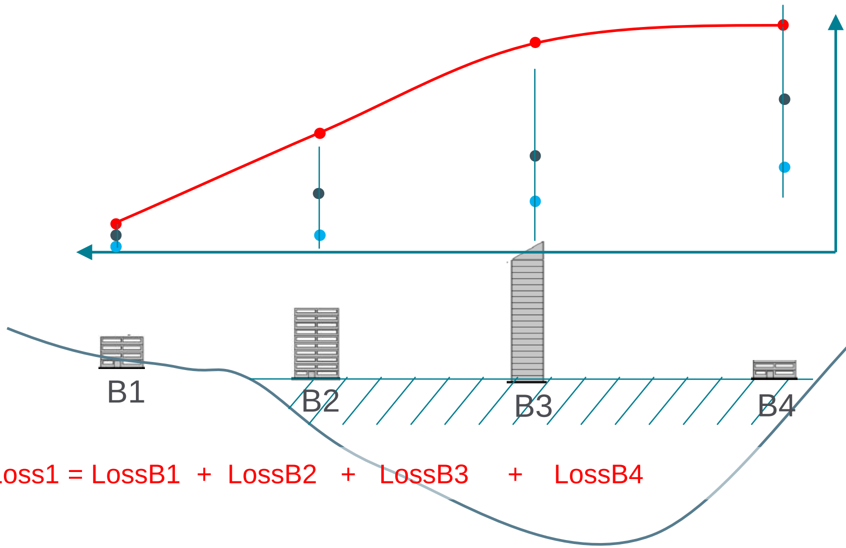




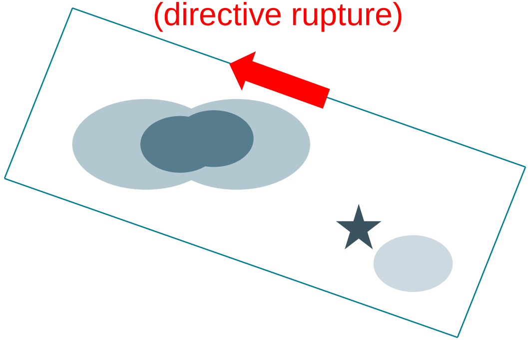
PBS based approach, GM(Si) = f(M,R,S,...
slip pattern, hypocenter, 3D alluvial basin, soil non linearities, topography)

How to use PBS into PRA: “Footprint based” approach

Event	Loss	Event Freq.
1	Loss1	Freq1



Simulation 1
(directive rupture)



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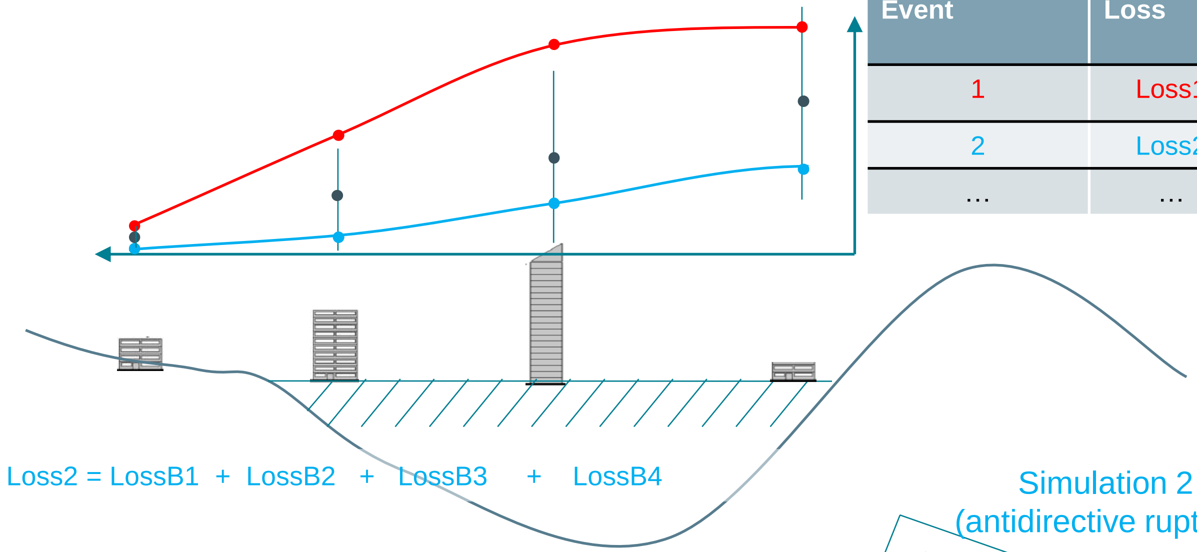
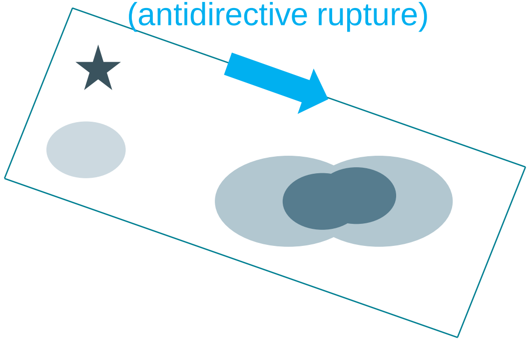
slip pattern, hypocenter, 3D alluvial basin, soil non linearities, topography)

How to use PBS into PRA: “Footprint based” approach

Event	Loss	Event Freq.
1	Loss1	Freq1
2	Loss2	Freq2
…	…	…





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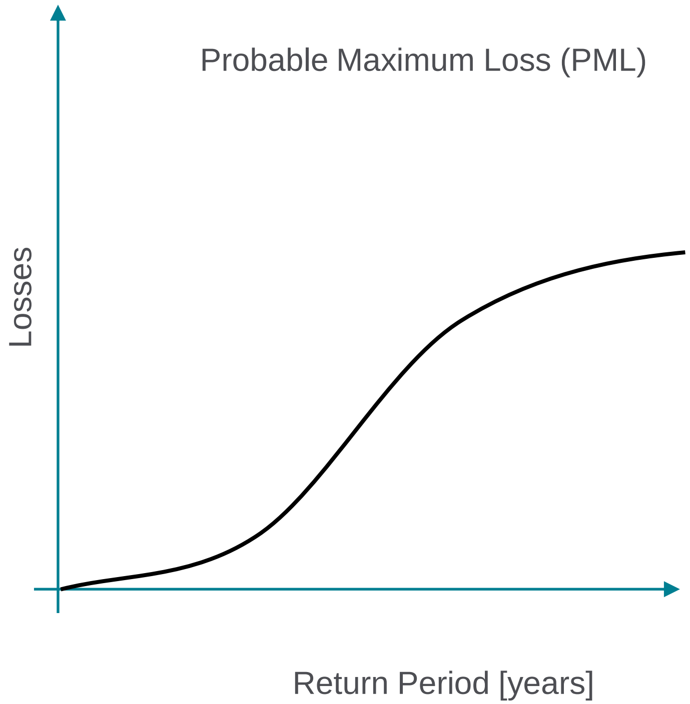
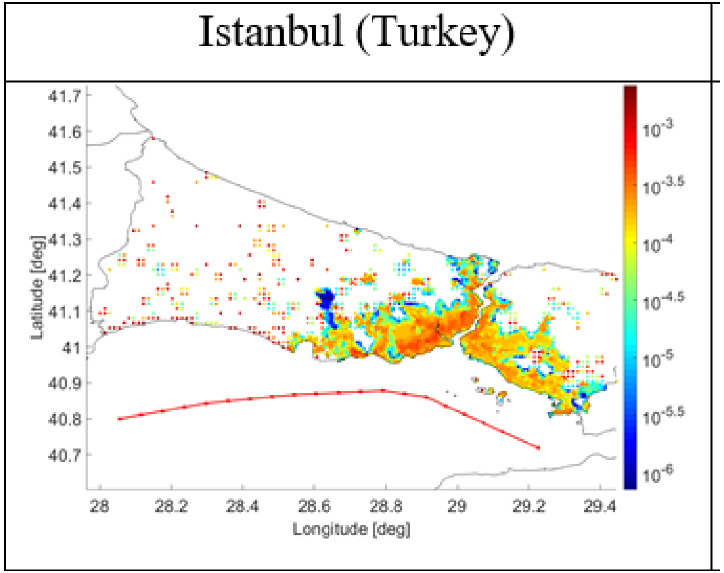
slip pattern, hypocenter, 3D alluvial basin, soil non linearities, topography)

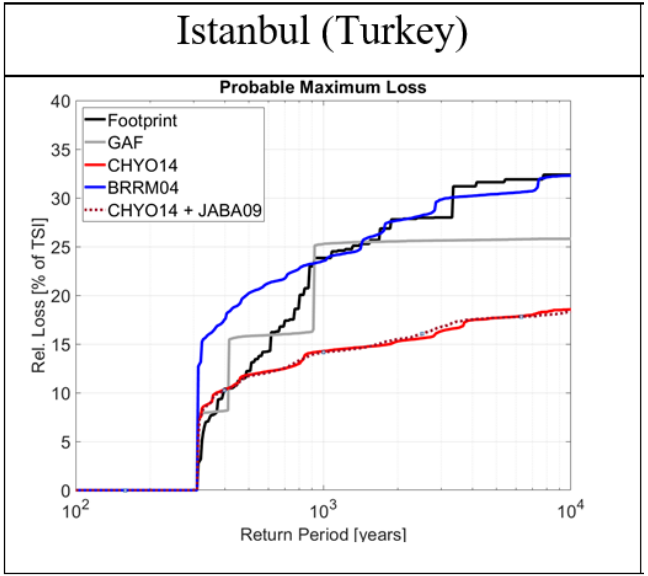
How to use PBS into PRA: “Footprint based” approach

Event	Loss	Event Freq.
1	Loss 1	Freq 1
2	Loss 2	Freq 2
3	Loss 3	Freq 3
4	Loss 4	Freq 4
5	Loss 5	Freq 5
6	Loss 6	Freq 6
7	Loss 7	Freq 7
8	Loss 8	Freq 8
9	Loss 9	Freq 9
…	…	…
n	Loss n	Freq n



PRA results according to the "Footprint based" approach against classical approaches





Footprint: pml based on physics-based footprints
GAF: Generalized Attenuation Function (see Villani et al., 2014)
CHYO14: pml based on Chiou&Youngs 2014 ground motion model
BRRM04: pml based on Bray&Rodriguez-Marek 2004 ground motion model
CHYO14 + JABA09: pml based on Chiou&Youngs 2014 ground motion model including the spatial correlation model of Jayaram&Baker 2009

Stupazzini M., Infantino M., Allmann A., Paolucci R., 2020. „Physics based probabilistic seismic hazard and loss assessment in large urban areas: A simplified application to Istanbul", Earthquake Engineering & Structural Dynamics 50(2), 99-115, DOI: 10.1002/eqe.3365

Overview of case studies by SPEED

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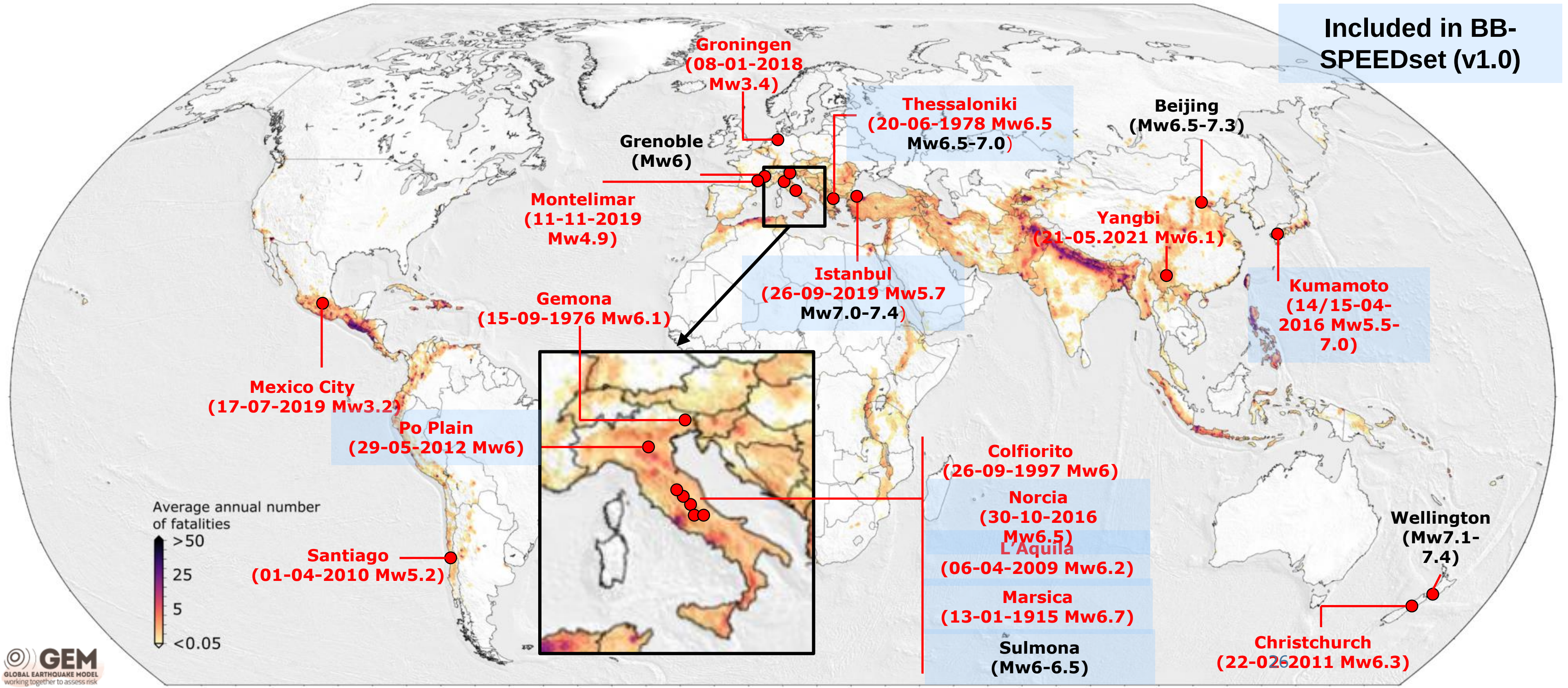

BB-SPEEDset: a dataset of near-source physics-based simulated accelerograms

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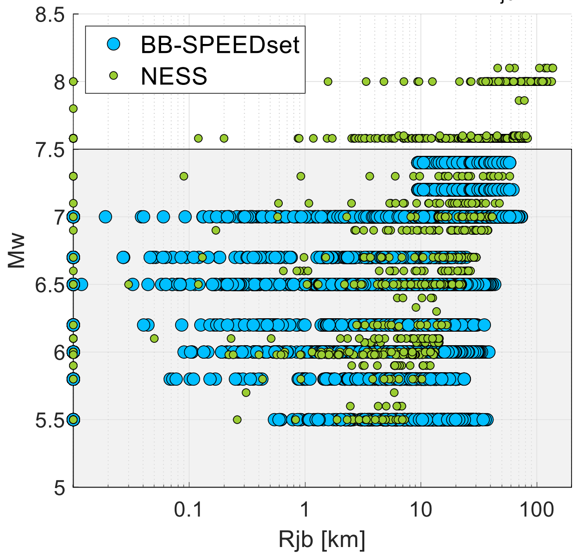
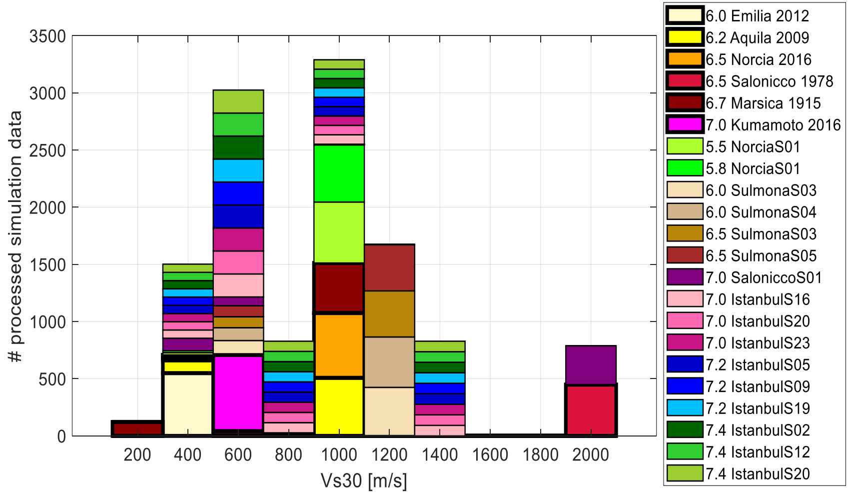
M_w- R_{jb} and V_{S30} distribution of BB-SPEEDset

NESS2.0 (Sgobba et al. 2021)





BB-SPEEDset: A Validated Dataset of Broadband Near-Source Earthquake Ground Motions from 3D Physics-Based Numerical Simulations

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Open-source:
http://speed.mox.polimi.it/bb-speedset/

- Flatfile
- 3-component broadband accelerograms (~12’000)

Status-quo

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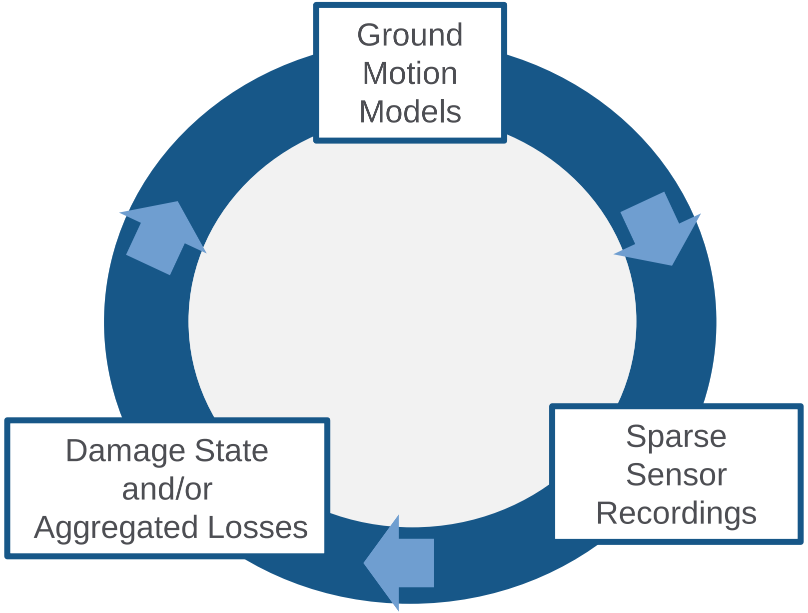
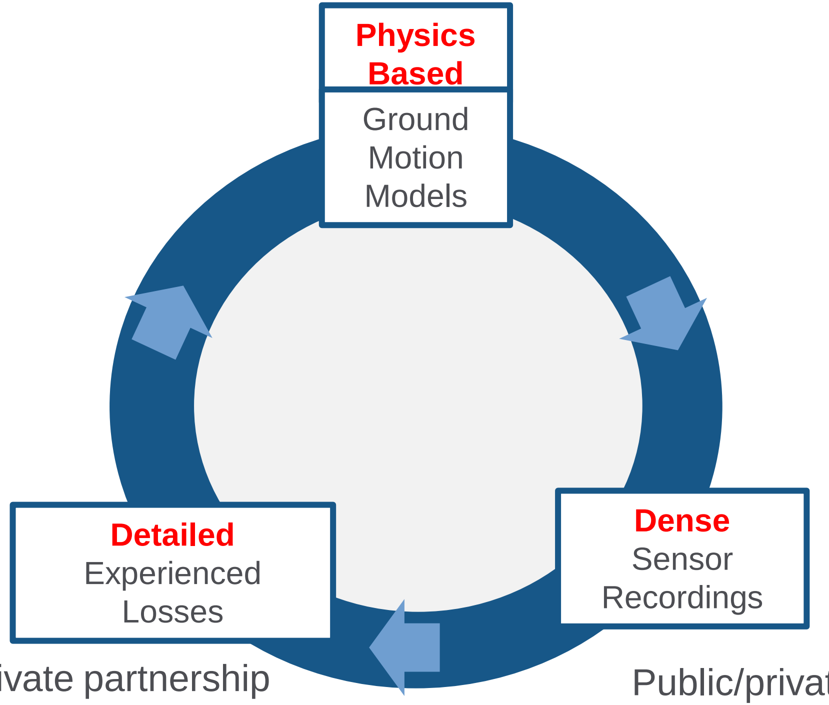
Property Catastrophic Modelling



Future directions

Scientific community



Public/private partnership

(re)insurance sector

Public/private partnership

Conclusions:
„Physics-Based Ground Motion Modelling“ community

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Was able to…

- generate a large amount of verified and validated physics-based simulations worldwide,
- challenge and improve the quality of Physics-Based Silumations (PBS) according to different quantitative metrics criteria,
- identify scientific research fields, presently under investigation.

TO DO:

- PBSs tend not to be collected into a global repository in contrary to what other community have achieved (e.g.: GEM Global Earthquake Model);
- it is difficult to obtain already simulated PBSs and to make use of the different published results;
- still missing common standard to store PBSs results.

The accomplishment of the TO DO‘s will drastically accelerate the adoption and therefore testing of PBSs in Seismic Risk Assessment.

Thanks for your attention!

Credit: mauritius images / ClickAlps

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