HORIZON 2020

ExchangeRisk

EXperimental & **C**omputational **H**ybrid **A**ssessment of **N**atural **G**as Pipelines **E**xposed to Seismic **Risk**

Post-event risk assessment for gas pipelines at regional scale:

The Friuli case

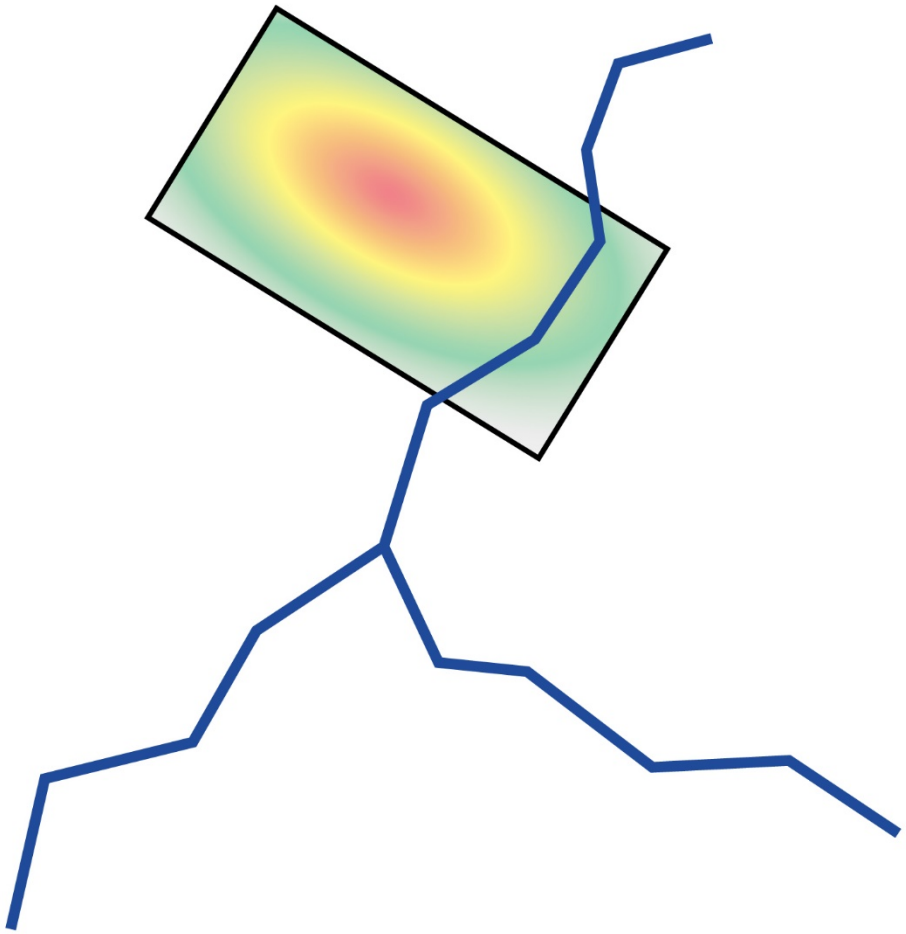
Hazard Model and Preliminary Simulations

Raffaele De Risi

Outline

- Transport gas pipeline

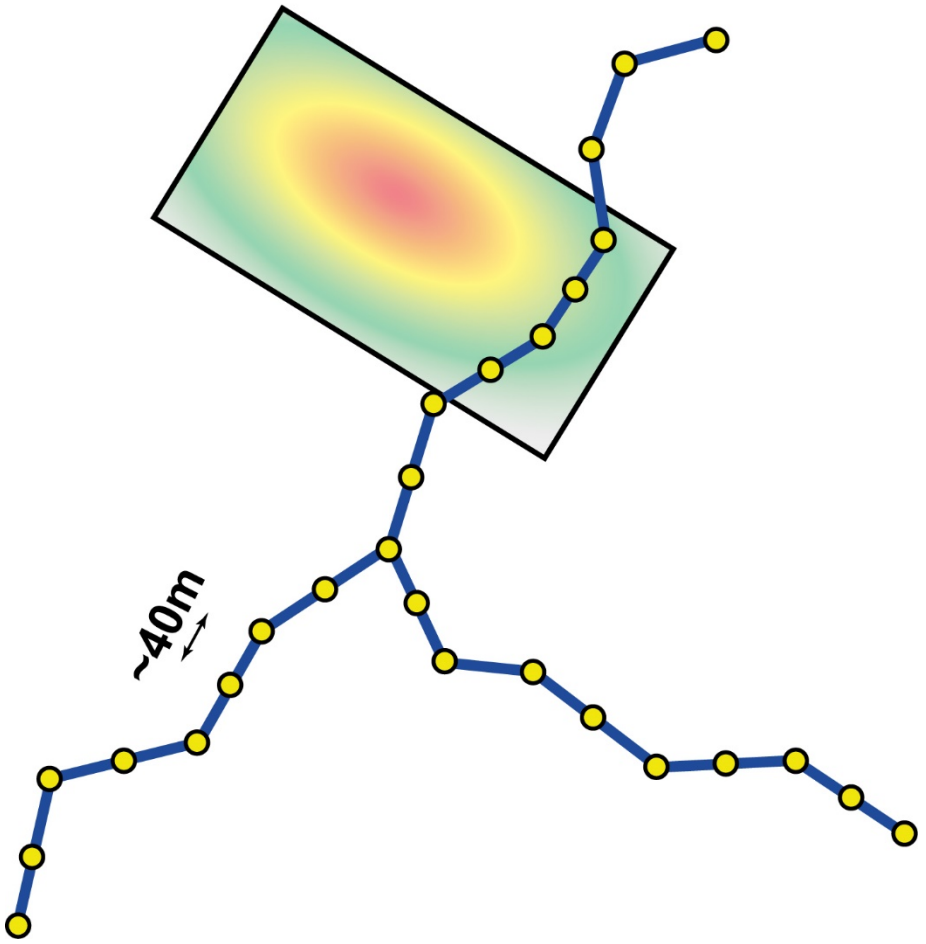
Outline



- Transport gas pipeline

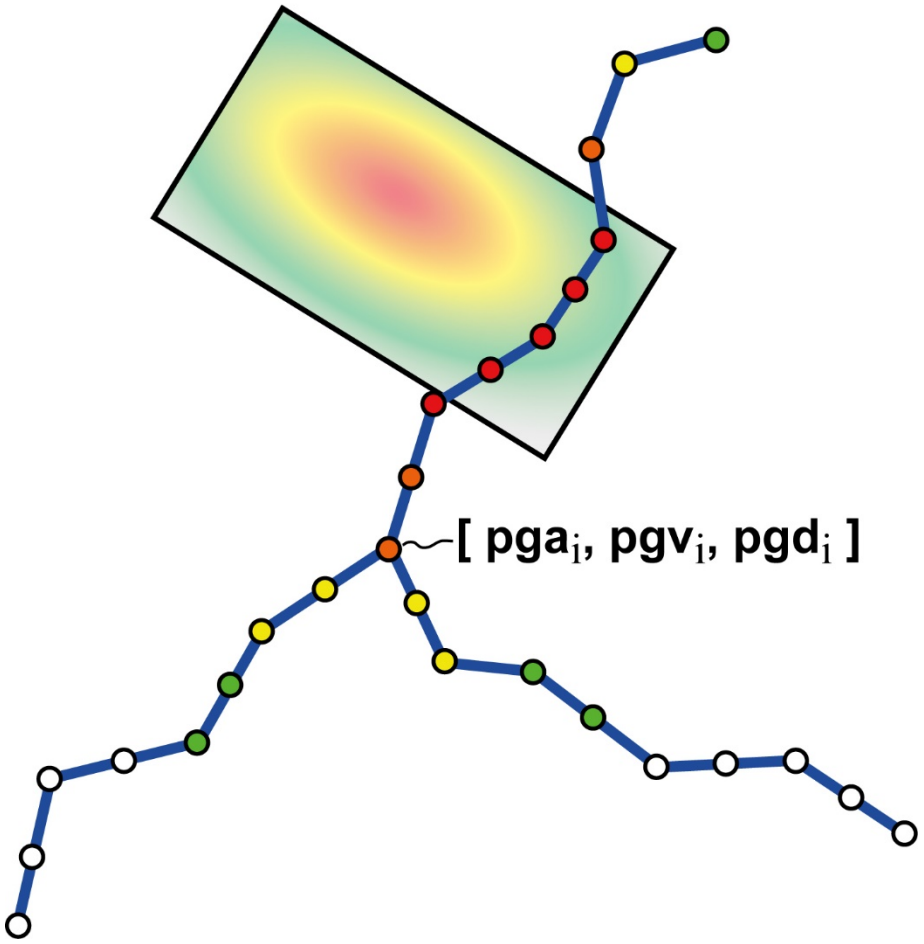
- Seismic event

Outline



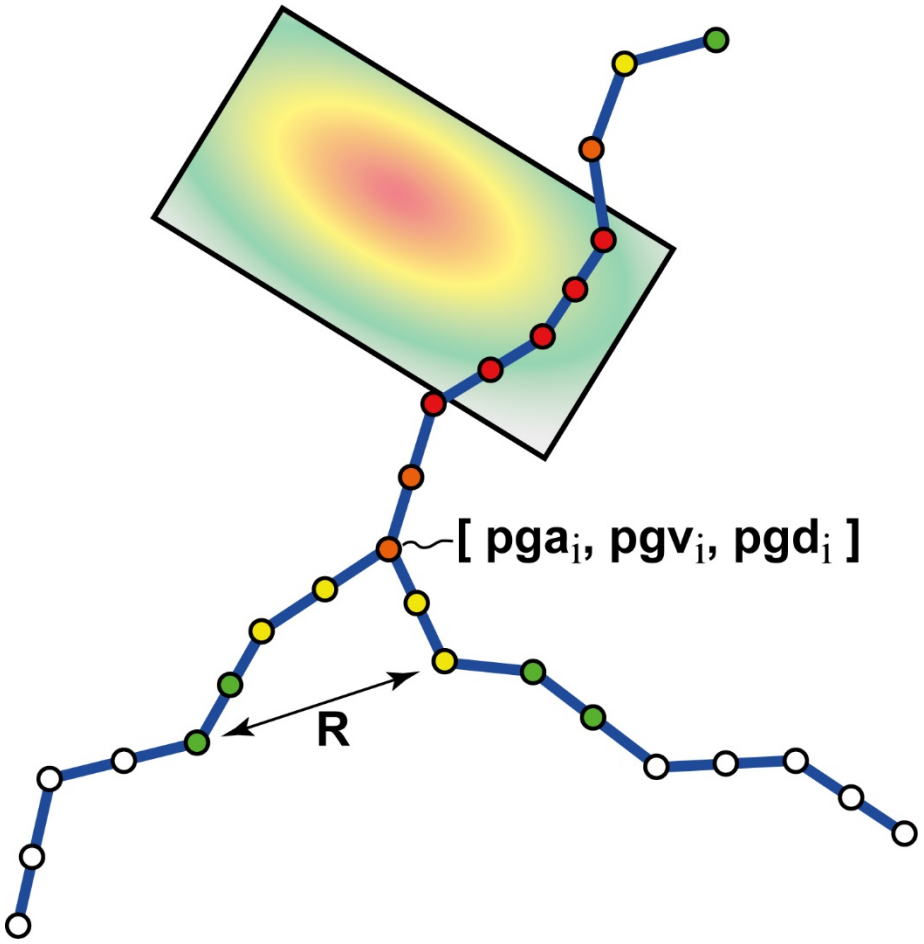
- Transport gas pipeline
- Seismic event
- Lifeline discretization

Outline



- Transport gas pipeline
- Seismic event
- Lifeline discretization
- Simulations of IMs fields

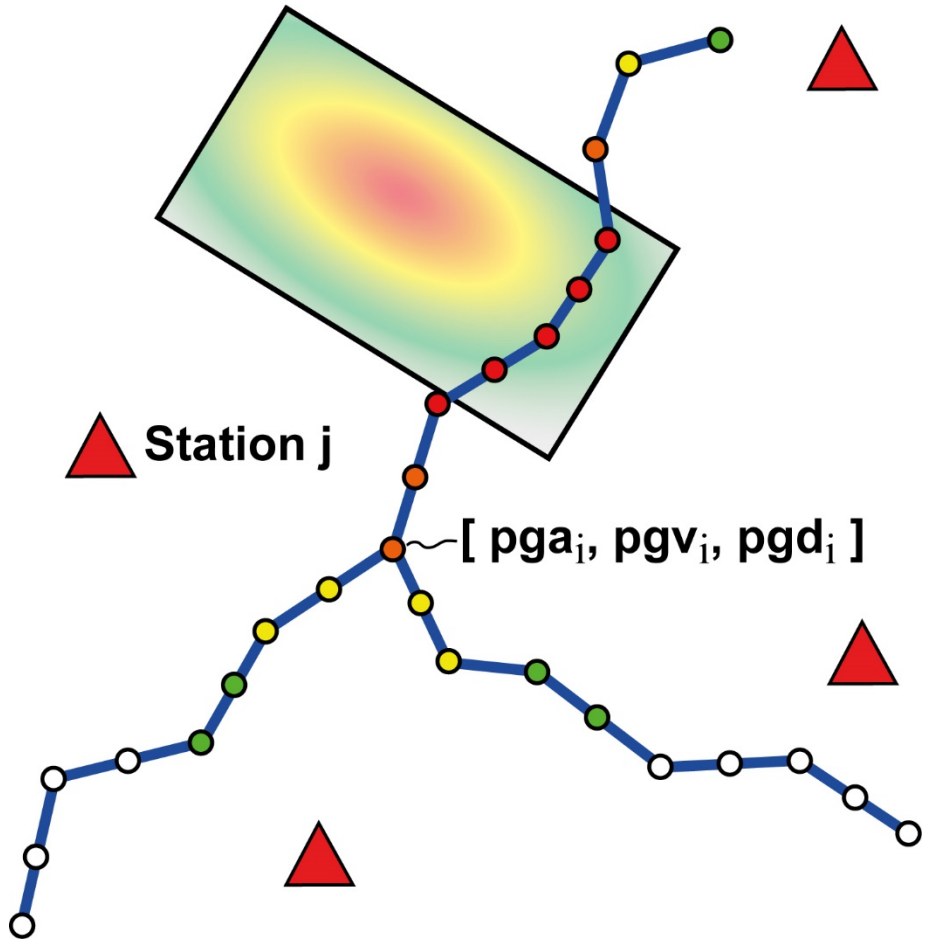
Outline



- Transport gas pipeline
- Seismic event
- Lifeline discretization
- Simulations of IMs fields
  - Spatial correlation
  - IMs cross-correlation

University of BRISTOL

Outline



- Transport gas pipeline
- Seismic event
- Lifeline discretization
- Simulations of IMs fields
  - Spatial correlation
  - IMs cross-correlation
- Updating with stations data

IMs Fields Simulations

$$\log(\mathbf{IM}) = \mathrm{N}\left(\log\left(\overline{\mathbf{IM}}\right),\ \ \phi^2 \cdot \mathbf{R}\right)$$

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Σ

IMs Fields Simulations

$$\log(\mathbf{IM}) = \mathrm{N}\left(\log\left(\overline{\mathbf{IM}}\right), \phi^2 \cdot \mathbf{R}\right) \rightarrow \Sigma$$

- **IM**: simulated intensity measures;
- $\overline{\mathbf{IM}}$: central estimates obtained through proper GMPEs;
- ϕ: intra-event standard error of selected GMPEs;
- **R**: correlation matrix;

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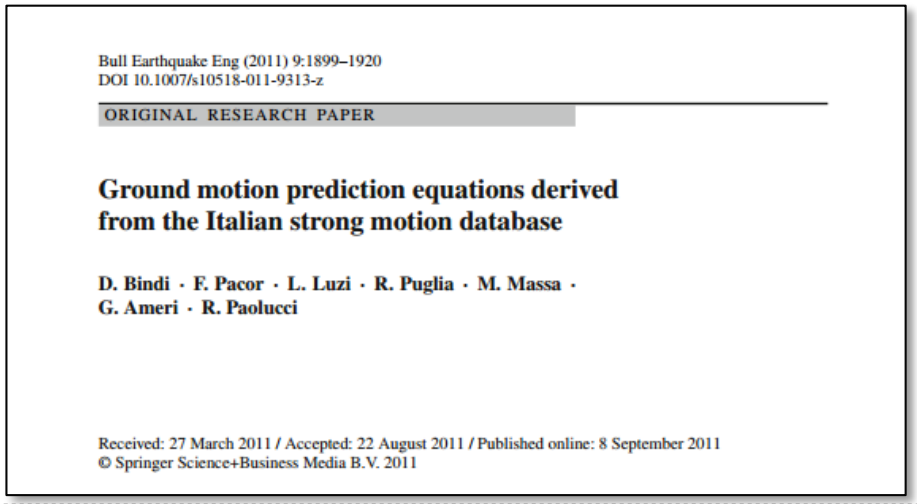

Bull Earthquake Eng (2011) 9:1899–1920
DOI 10.1007/s10518-011-9313-z

ORIGINAL RESEARCH PAPER

Ground motion prediction equations derived from the Italian strong motion database

D. Bindi · F. Pacor · L. Luzi · R. Puglia · M. Massa · G. Ameri · R. Paolucci

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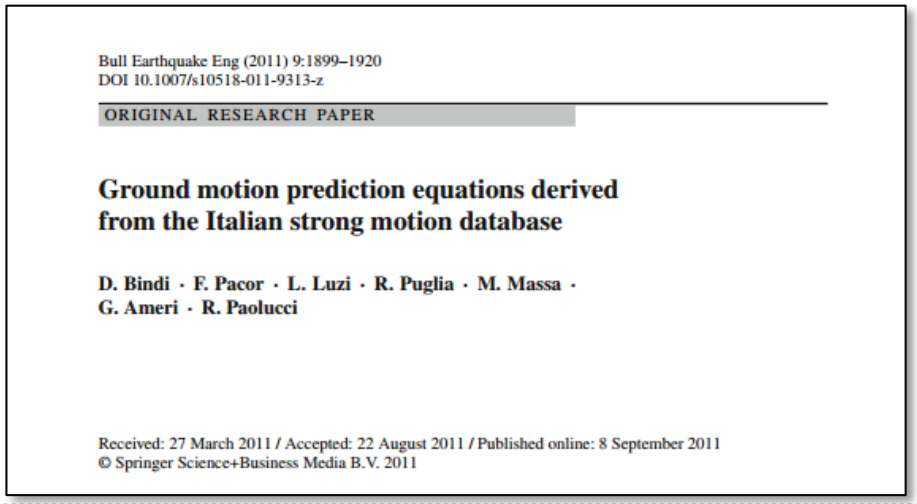

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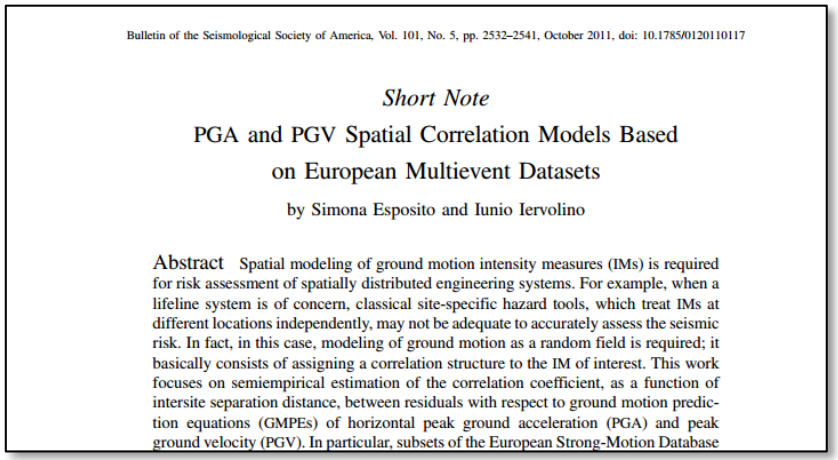

Bulletin of the Seismological Society of America, Vol. 101, No. 5, pp. 2532–2541, October 2011, doi: 10.1785/0120110117

Short Note

PGA and PGV Spatial Correlation Models Based on European Multievent Datasets

by Simona Esposito and Iunio Iervolino

Abstract Spatial modeling of ground motion intensity measures (IMs) is required for risk assessment of spatially distributed engineering systems. For example, when a lifeline system is of concern, classical site-specific hazard tools, which treat IMs at different locations independently, may not be adequate to accurately assess the seismic risk. In fact, in this case, modeling of ground motion as a random field is required; it basically consists of assigning a correlation structure to the IM of interest. This work focuses on semiempirical estimation of the correlation coefficient, as a function of intersite separation distance, between residuals with respect to ground motion prediction equations (GMPEs) of horizontal peak ground acceleration (PGA) and peak ground velocity (PGV). In particular, subsets of the European Strong-Motion Database

IMs Fields Simulations

$$\log(\mathbf{IM}) = \mathrm{N}\left(\log\left(\overline{\mathbf{IM}}\right), \phi^2 \cdot \mathbf{R}\right) \rightarrow \Sigma$$

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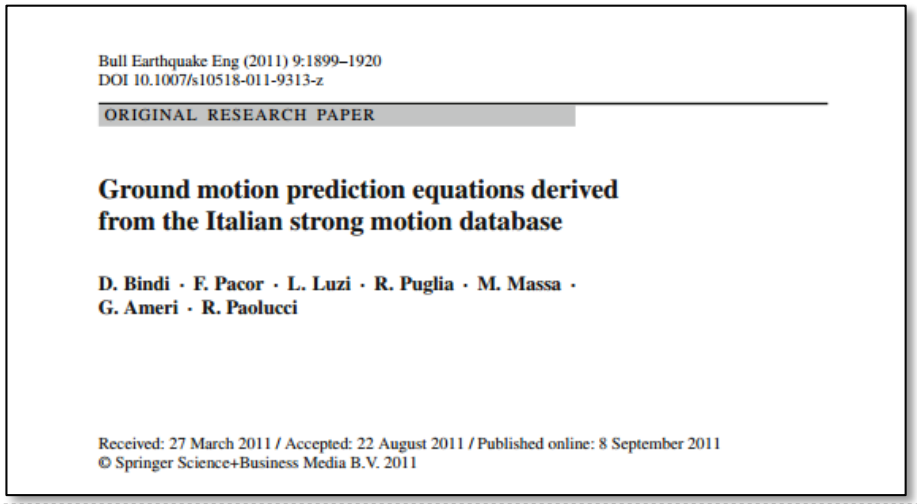

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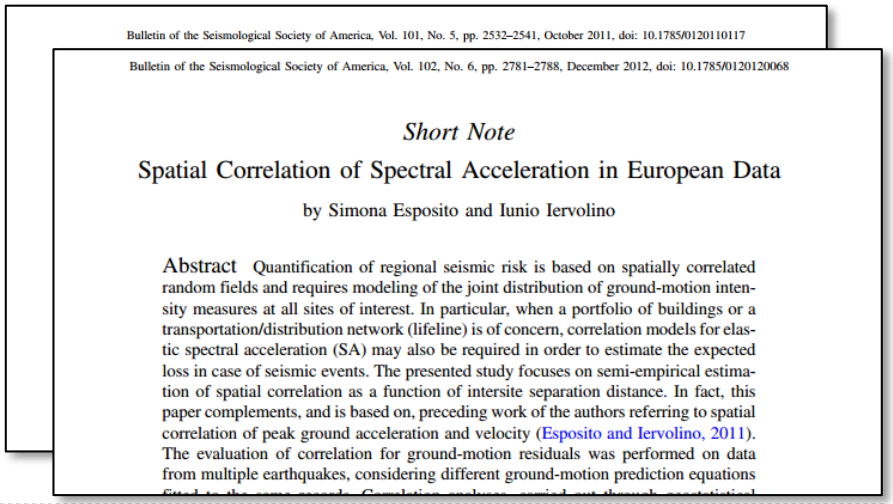

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Bulletin of the Seismological Society of America, Vol. 102, No. 6, pp. 2781–2788, December 2012, doi: 10.1785/0120120068

Short Note

Spatial Correlation of Spectral Acceleration in European Data

by Simona Esposito and Iunio Iervolino

Abstract Quantification of regional seismic risk is based on spatially correlated random fields and requires modeling of the joint distribution of ground-motion intensity measures at all sites of interest. In particular, when a portfolio of buildings or a transportation/distribution network (lifeline) is of concern, correlation models for elastic spectral acceleration (SA) may also be required in order to estimate the expected loss in case of seismic events. The presented study focuses on semi-empirical estimation of spatial correlation as a function of intersite separation distance. In fact, this paper complements, and is based on, preceding work of the authors referring to spatial correlation of peak ground acceleration and velocity (Esposito and Iervolino, 2011). The evaluation of correlation for ground-motion residuals was performed on data from multiple earthquakes, considering different ground-motion prediction equations

IMs Fields Simulations

IMs Fields Simulations

Five cases:

1) IMs uncorrelated;
2) IMs spatially correlated; (Goda & Hong 2008)
3) IMs spatially correlated and cross-correlated; (Weatherill et al. 2014)
4) Case 2 updated with data from stations; (Miano et al. 2016)
5) Case 3 updated with data from stations. (Miano et al. 2016)

IMs Fields Simulations

Five cases:

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5) Case 3 updated with data from stations. (Miano et al. 2016)

(3)

$$IM = \begin{bmatrix} PGA \\ PGV \end{bmatrix} \quad \Sigma = \begin{bmatrix} \Sigma_{PGA} & \Sigma_{PGA,\mathrm{PGV}} \\ \Sigma_{PGV,\mathrm{PG}\,A} & \Sigma_{PGV} \end{bmatrix}$$

(4,5)

$$IM = \begin{bmatrix} IM_1 \\ IM_2 \end{bmatrix} \quad \Sigma = \begin{bmatrix} \Sigma_{IM_1} & \Sigma_{IM_1,IM_2} \\ \Sigma_{IM_2,IM_1} & \Sigma_{IM_2} \end{bmatrix}$$

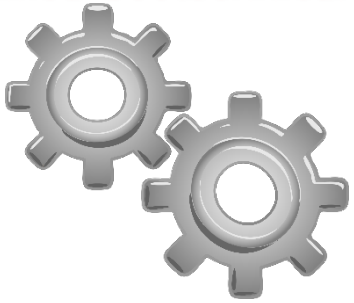
How to obtain PGD?

How to obtain PGD?

Simplified Geotechnical Models

PGA

PGV



PGD Landslide

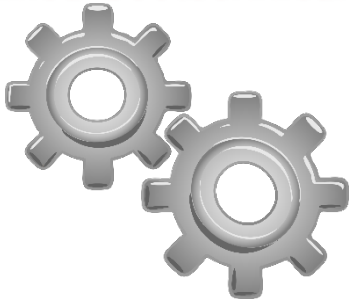
PGD Liquefaction

How to obtain PGD?

Simplified Geotechnical Models

PGA

PGV



PGD Landslide

PGD Liquefaction

Landslide and Liquefaction induced PGD

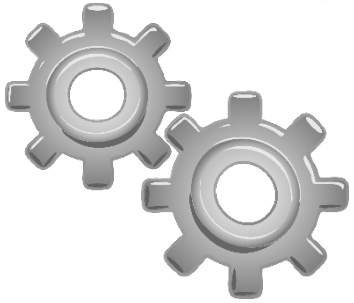
- Similar three-phases approach:

How to obtain PGD?

Simplified Geotechnical Models

PGA

PGV



PGD Landslide

PGD Liquefaction

Landslide and Liquefaction induced PGD

- Similar three-phases approach:

1

Susceptibility

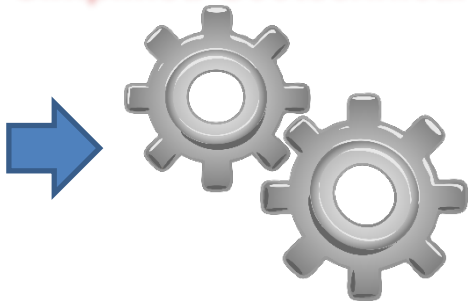
Based on Magnitude and Distance

How to obtain PGD?

Simplified Geotechnical Models

PGA

PGV



PGD Landslide

PGD Liquefaction

Landslide and Liquefaction induced PGD

- Similar three-phases approach:

1

Susceptibility

Based on Magnitude and Distance

2

Triggering

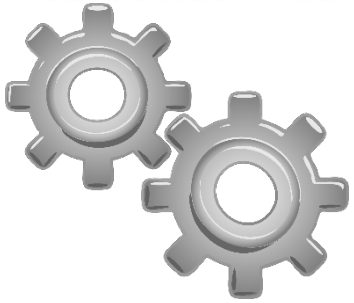
Demand & Capacity approach

How to obtain PGD?

Simplified Geotechnical Models

PGA

PGV



PGD Landslide

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Landslide and Liquefaction induced PGD

- Similar three-phases approach:

1

Susceptibility

Based on Magnitude and Distance

2

Triggering

Demand & Capacity approach

3

Displacements

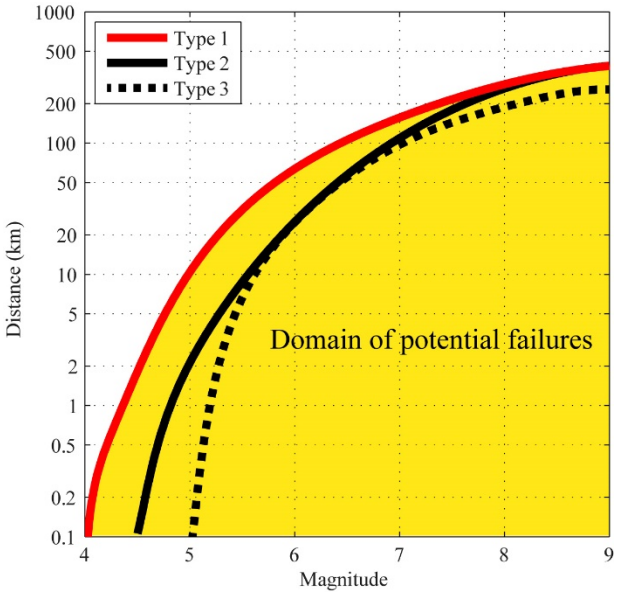
Based on empirical relationships

Landslide-induced PGD

Simplified Geotechnical Models

Susceptibility

Wilson & Keefer 1985

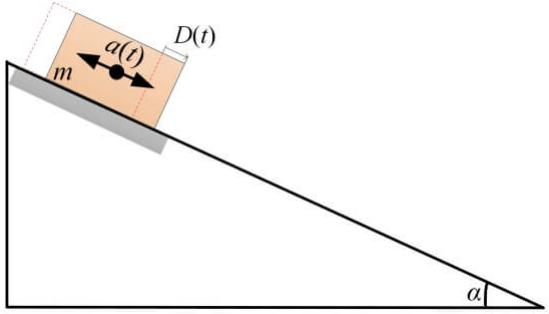


Validated for Italy

Triggering

Planar landslides

Newmark's method



$$FS = \frac{c'}{\gamma \cdot t \cdot \sin\alpha} + \frac{\tan\phi'}{\tan\alpha} - \frac{u \cdot \gamma_w \cdot \tan\phi'}{\gamma \cdot \tan\alpha}$$

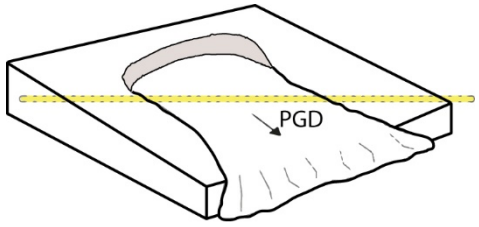
$$a_c = (FS - 1) \cdot g \cdot \sin\alpha$$

Displacements

Saygili & Rathje 2008

Function of PGA & PGV

$$\ln(D) = a_1 + a_2\left(\frac{a_c}{PGA}\right) + a_3\left(\frac{a_c}{PGA}\right)^2 + a_4\left(\frac{a_c}{PGA}\right)^3 + a_5\left(\frac{a_c}{PGA}\right)^4 + a_6 \ln(PGA) + a_7 \ln(PGV)$$

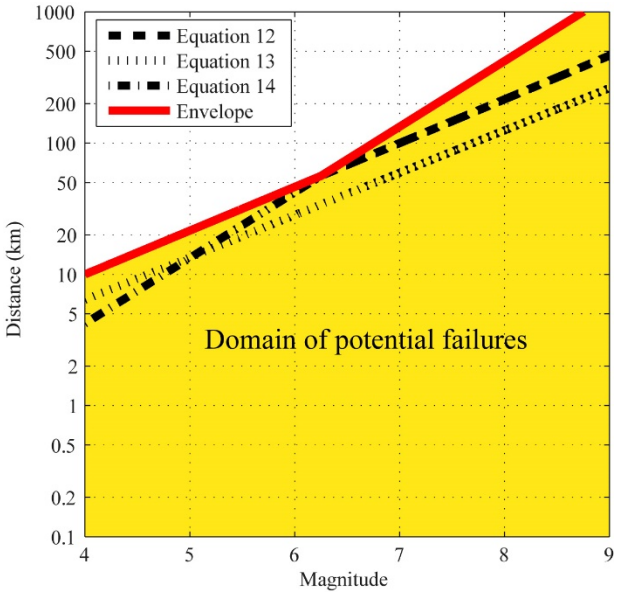


Liquefaction-induced PGD

Simplified Geotechnical Models

Susceptibility

Galli 2000



Bespoken for Italy

Triggering

Semi empirical method

Seed & Idriss 1971

$$FS = \frac{CSR}{CRR}$$

Vs based

Goda et al. 2011

Kayen et al. 2013

$$LPI = \int_0^{20} FS \cdot w(z) \cdot dz$$

LPI	Failure potential
0 ≤ LPI ≤ 5	Low
5 < LPI ≤ 15	High
LPI > 15	Extremely high

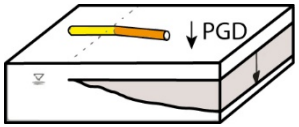
Displacements

LPI ≤ 5 $D = 0$

5 < LPI ≤ 15

Sand Boils: Settlements

Takada & Tanabe 1988

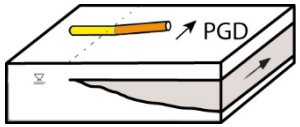


$$D = 0.3 \cdot H \cdot \frac{PGA}{N} + 2$$

LPI > 15

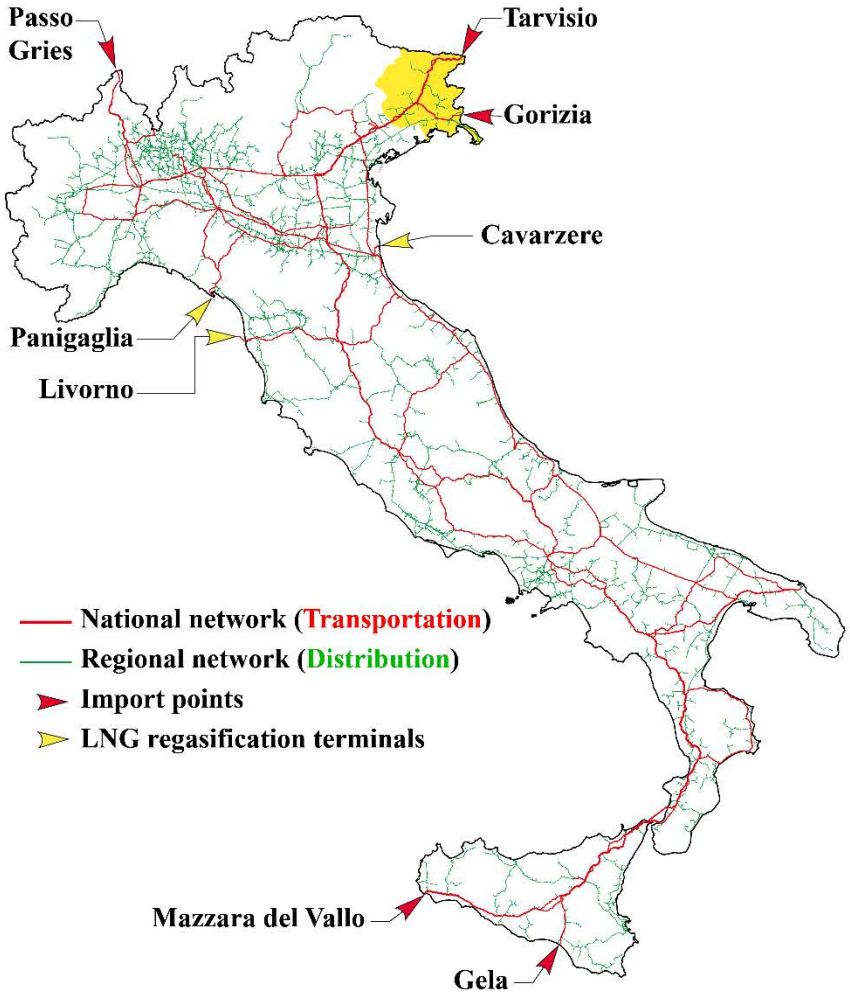
Sand Lateral Spreads:

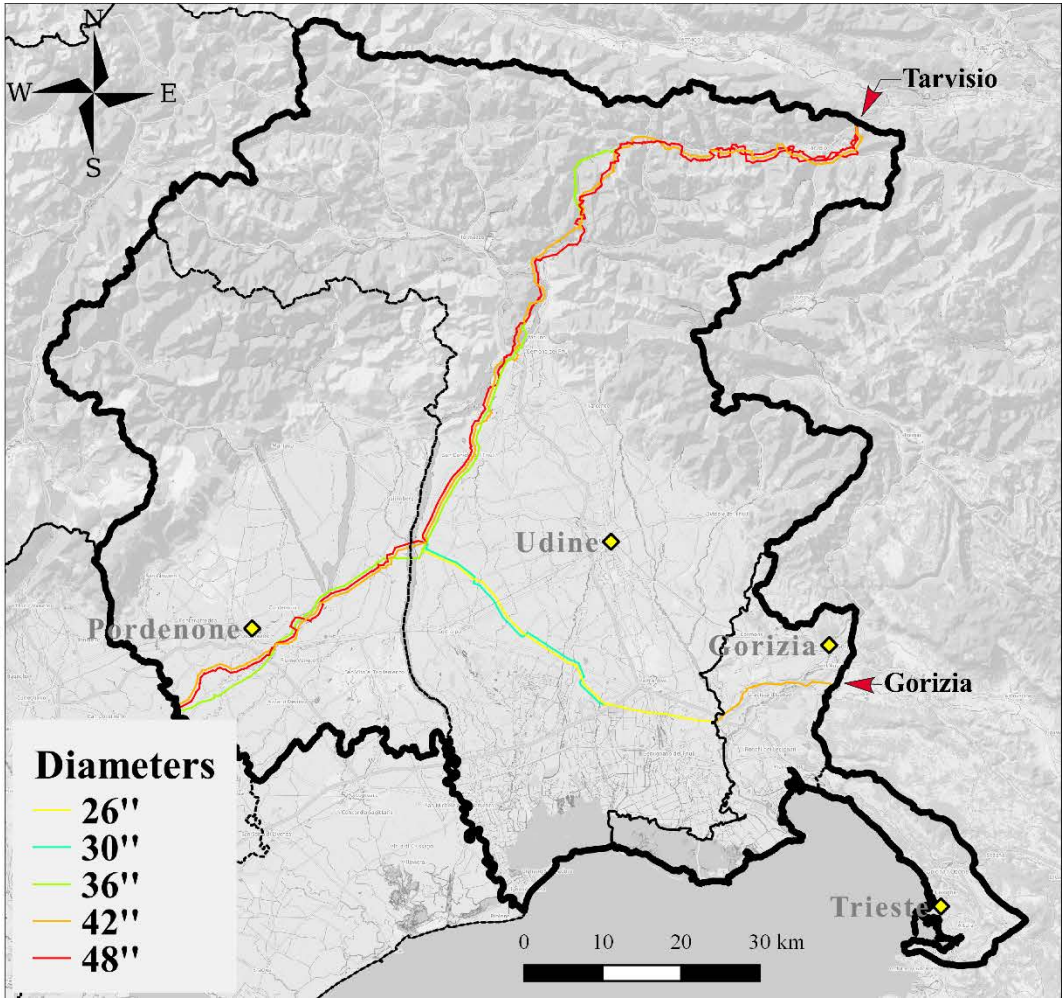
Bardet et al 1999



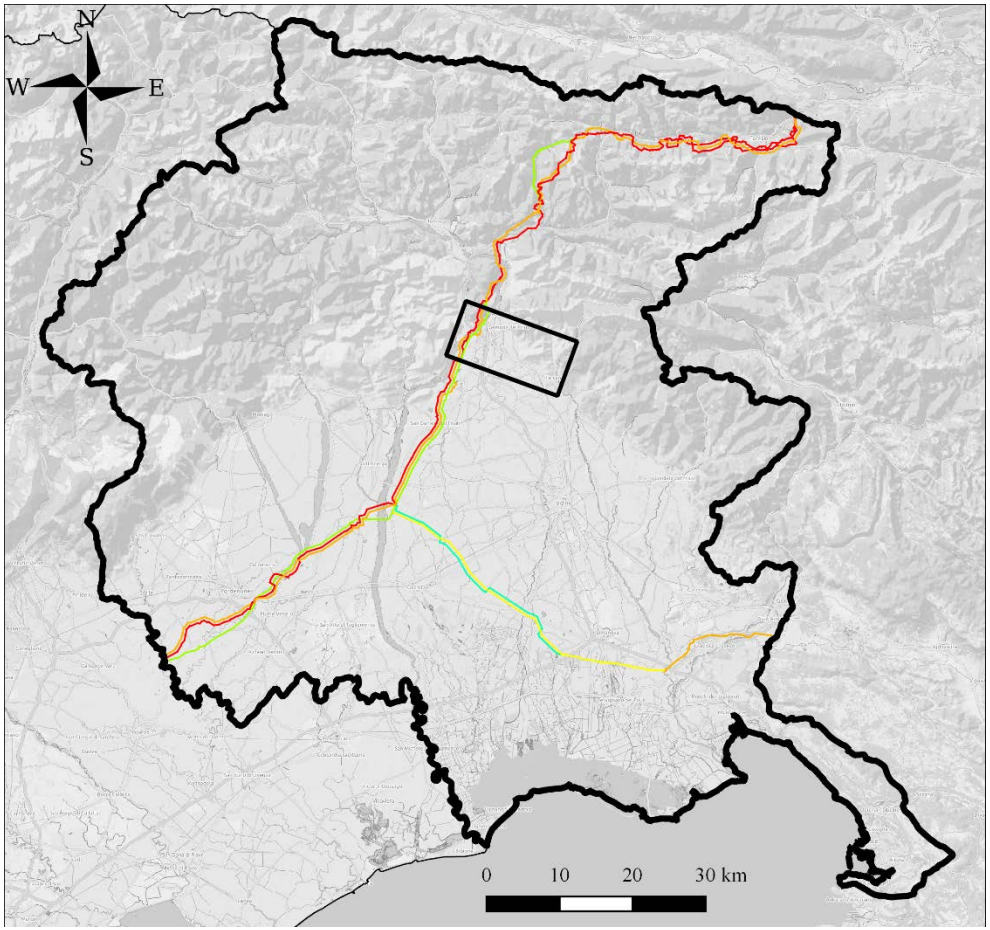
$$\log(D + 0.01) = \ldots$$
$$f(\mathrm{M}, R, S, T_{15})$$

Case study


Passo Gries
Tarvisio
Gorizia
Cavarzere
Panigaglia
Livorno
Mazzara del Vallo
Gela
National network (Transportation)
Regional network (Distribution)
Import points
LNG regasification terminals


N
W
E
S
Tarvisio
Udine
Pordenone
Gorizia
Gorizia
Trieste
Diameters
26"
30"
36"
42"
48"
0
10
20
30 km

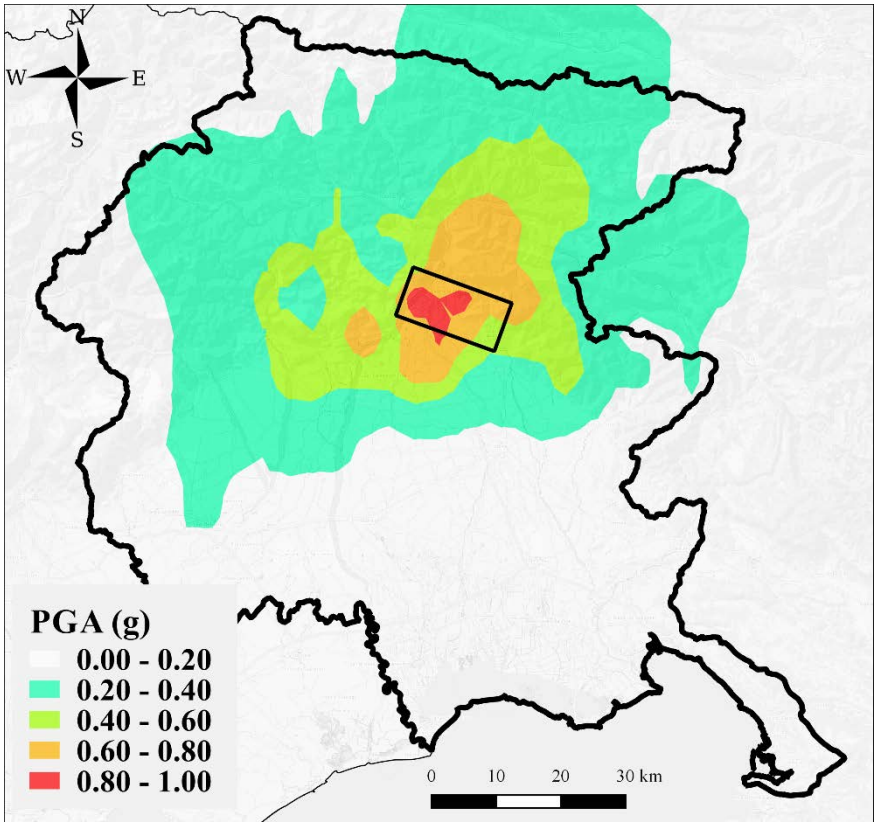
Case study

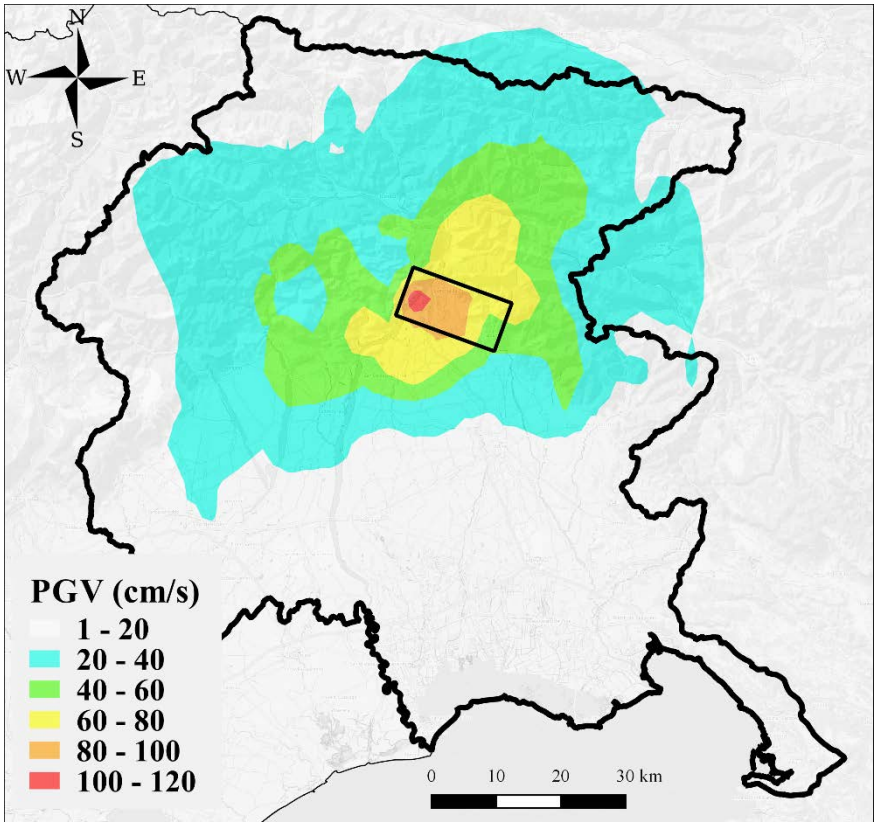


- Friuli earthquake
- May 6, 1976
- Mw: 6.4
- Max MMI: X
- Gemona fault
- Reverse fault
- Discretization ~ 40 m
- 10975 segments (~510 km)

Case study

USGS shake maps

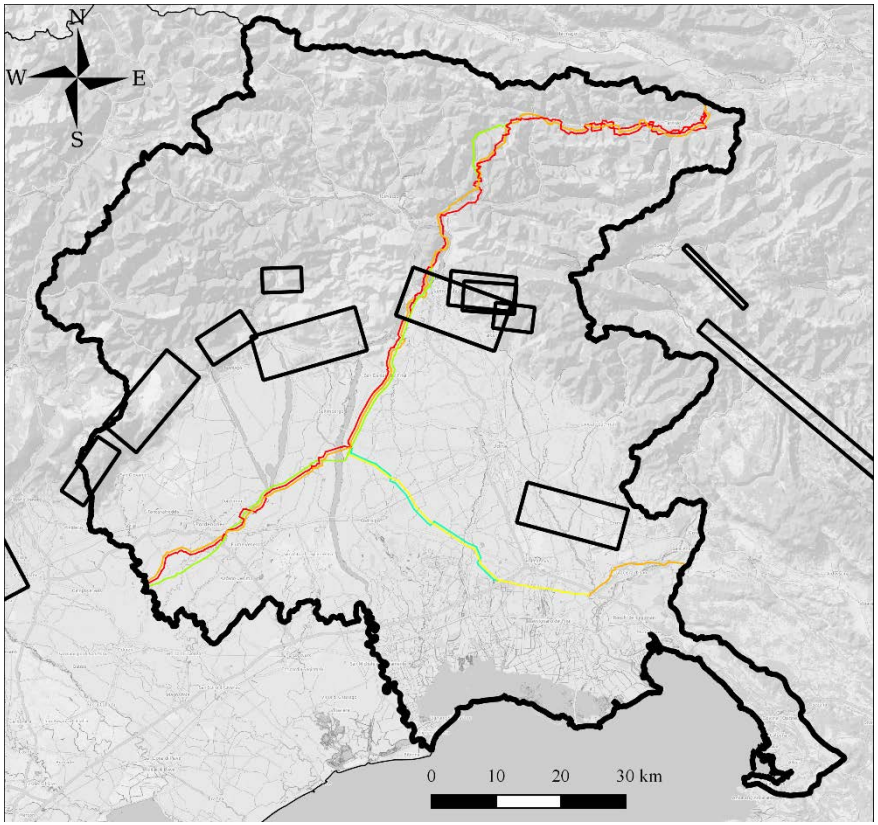




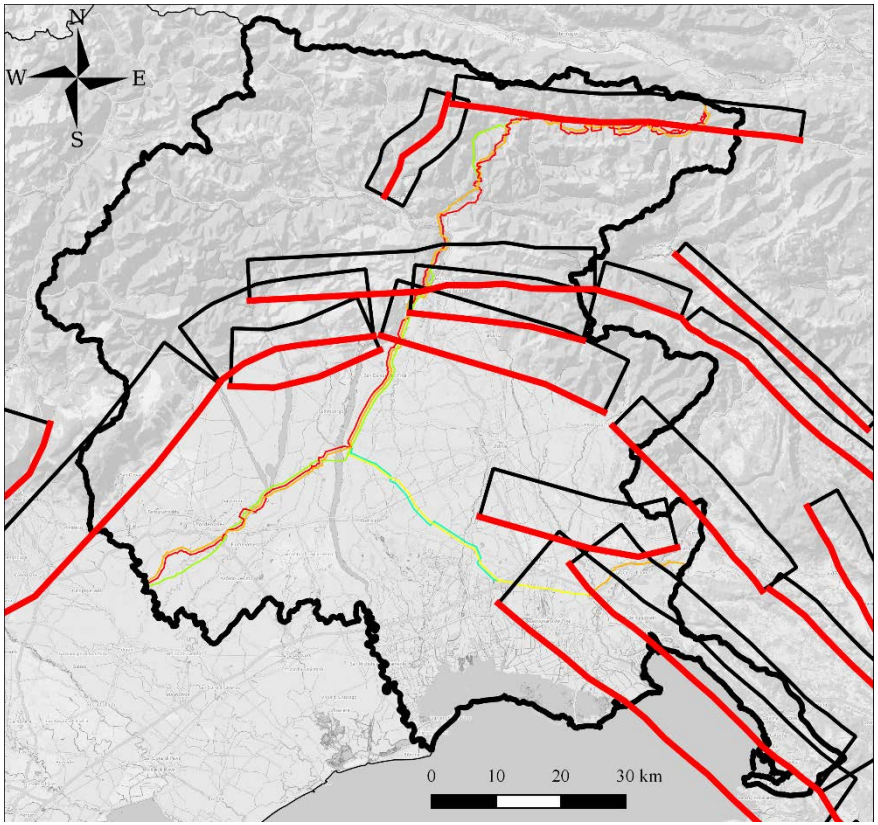
Case study

Seismogenetic context

Basili et al. 2008



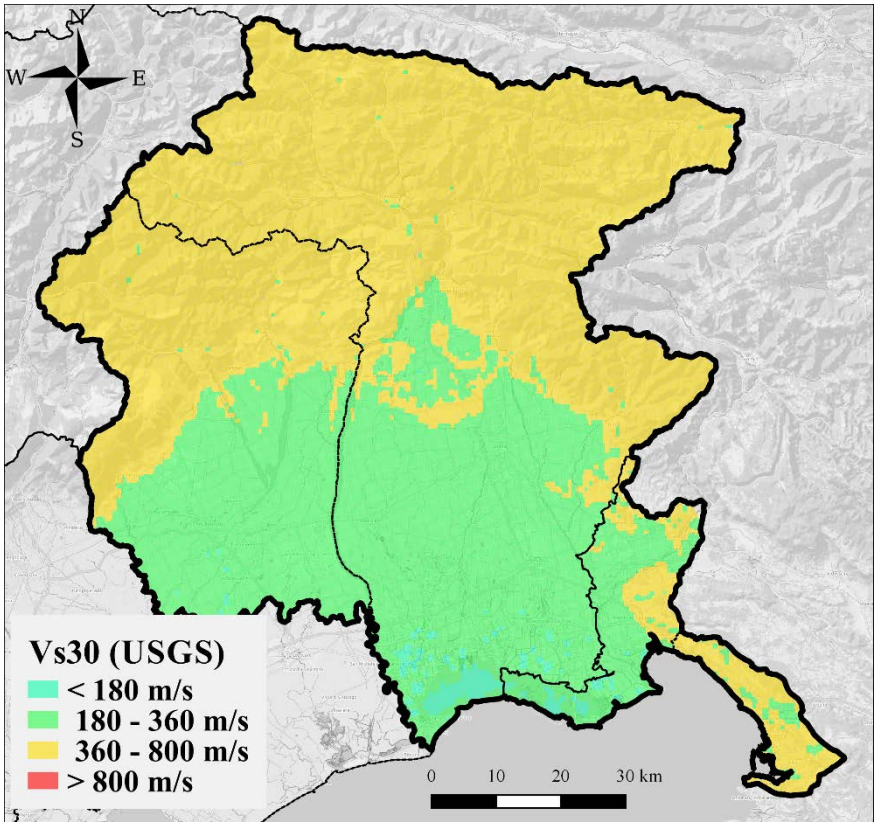
Individual seismic sources

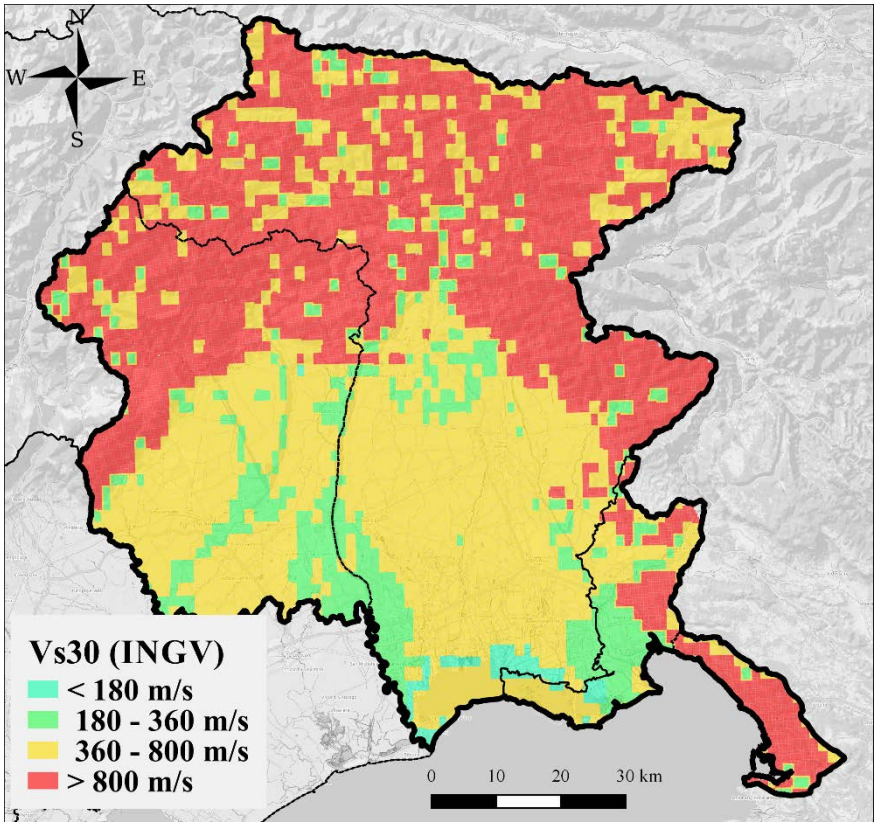


Distributed seismic sources

Case study: collected data

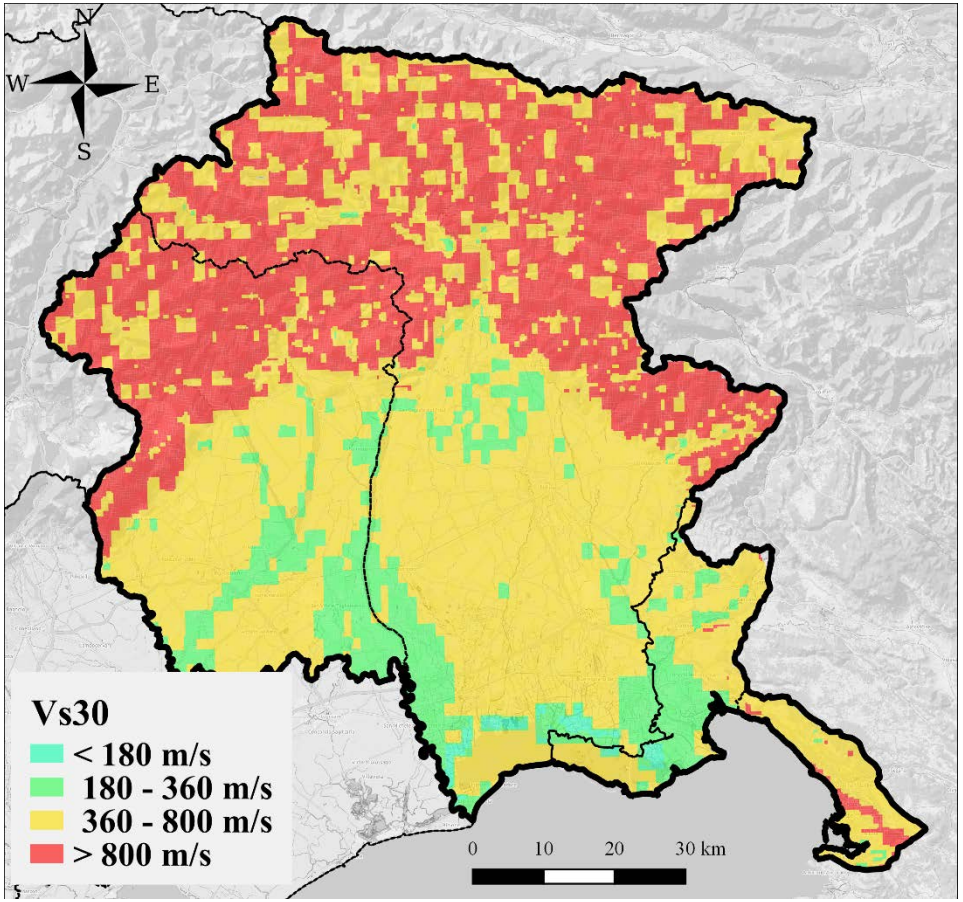
Vs 30 – shear wave velocity





Case study: collected data

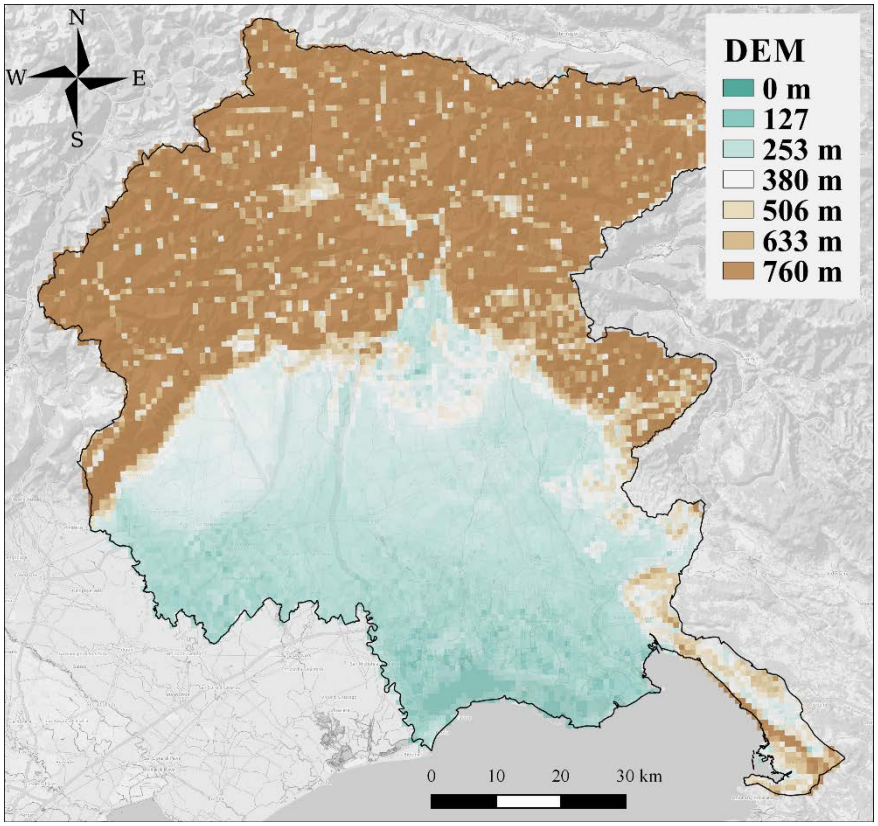
Vs 30 – shear wave velocity

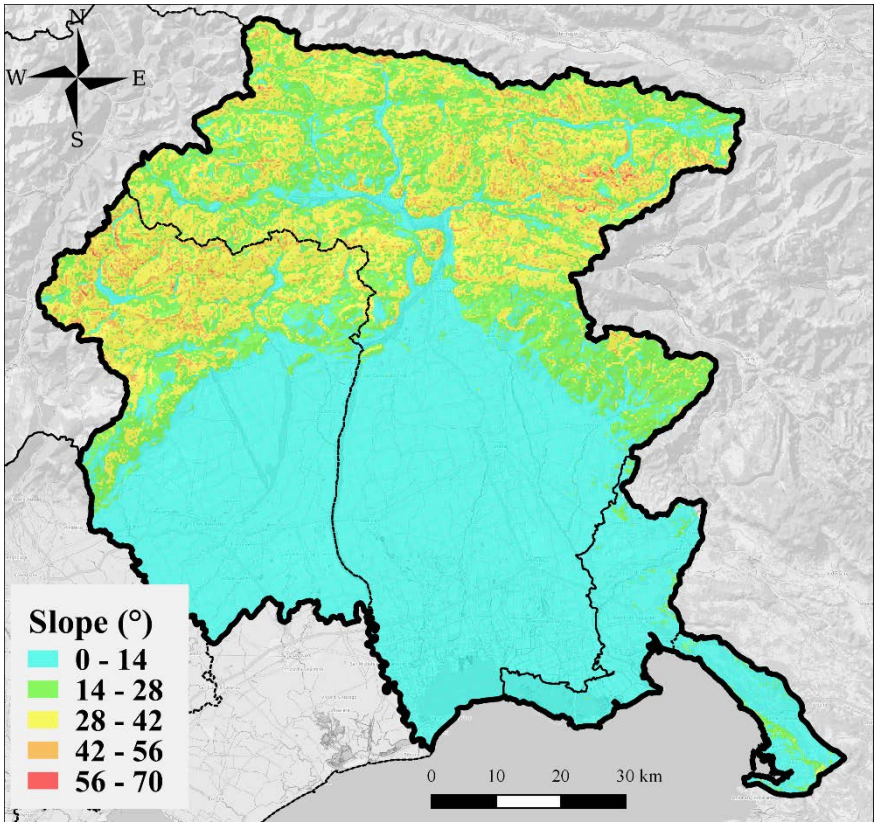


Case study: collected data

DEM and Slope

Res. 30 m

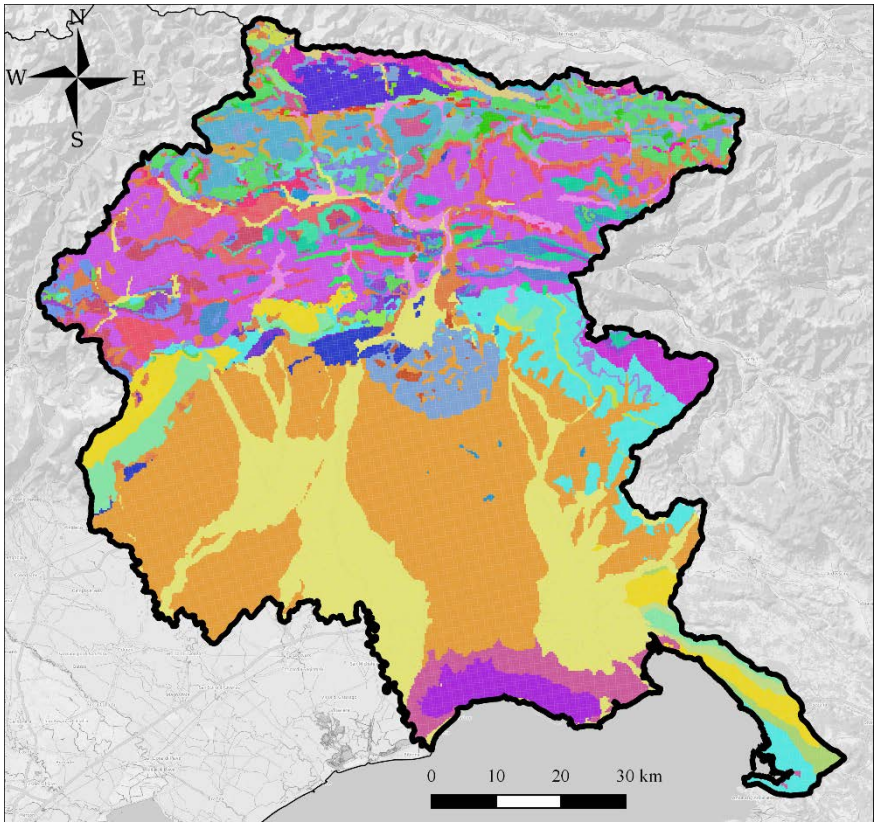


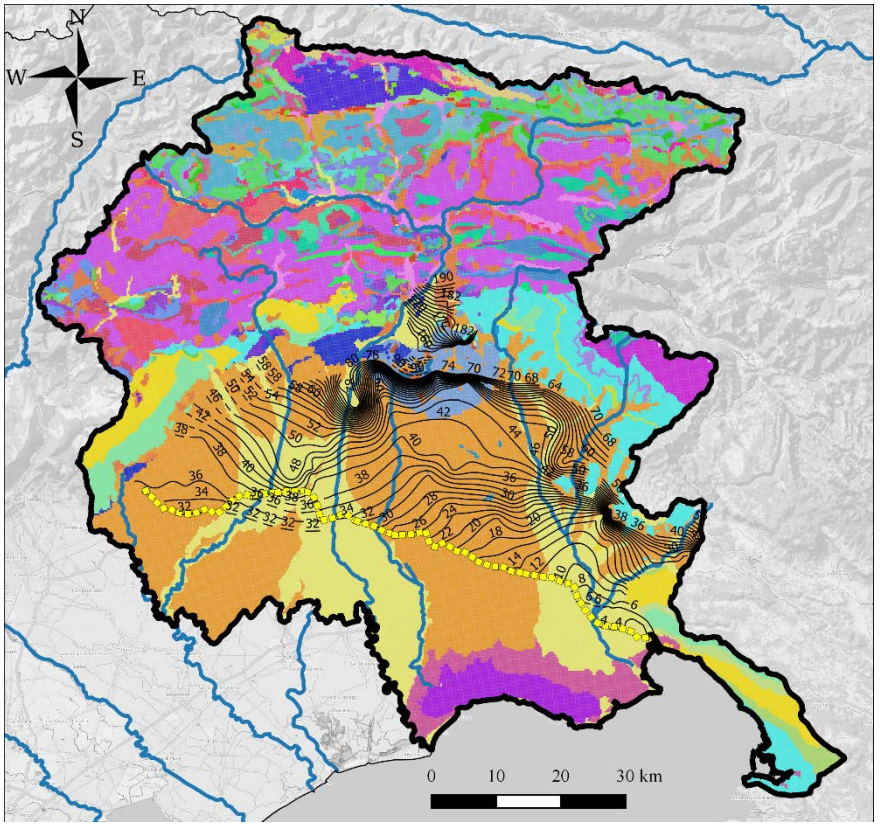


Case study: collected data

Geo-Lithology and Groundwater

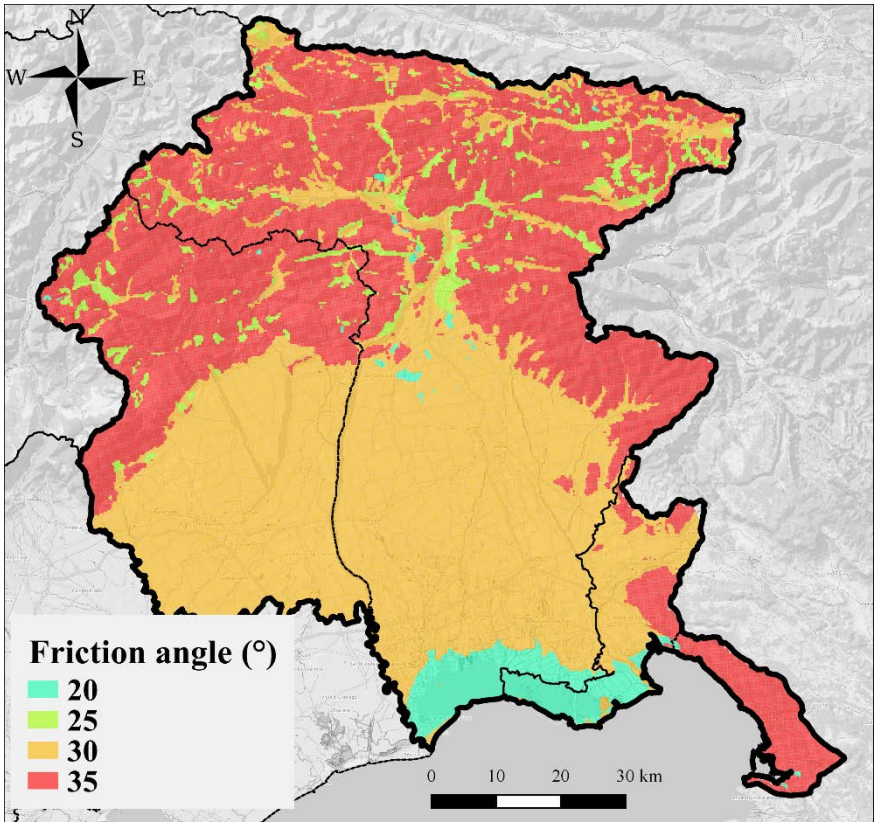
Res 1 : 50000

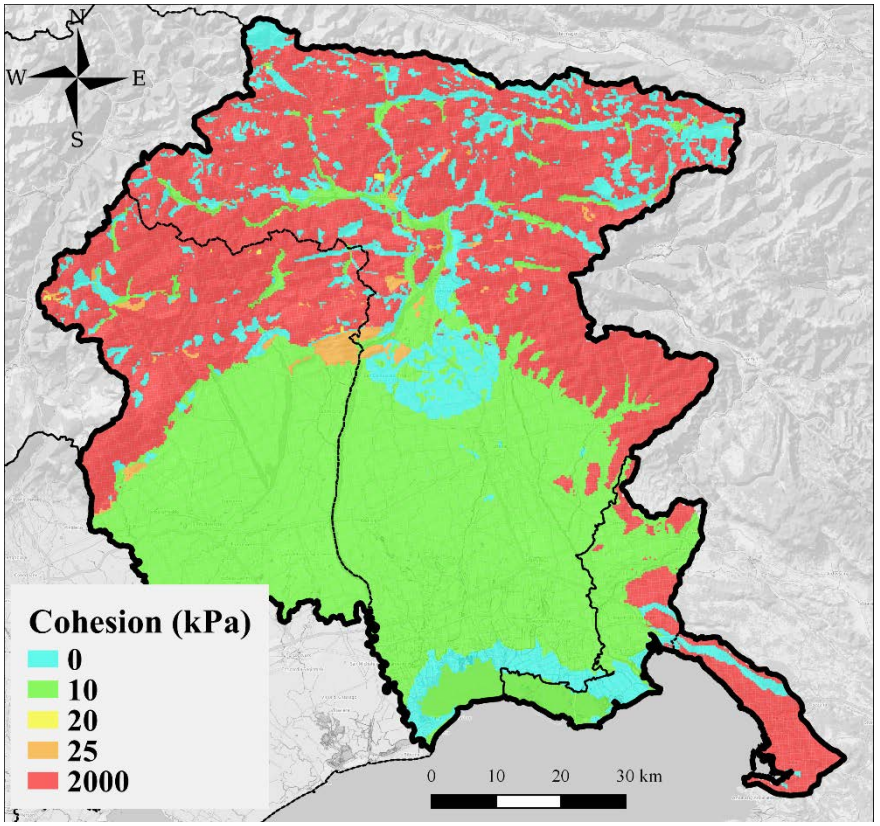




Case study: collected data

Geotechnical interpretation of geo-lithology





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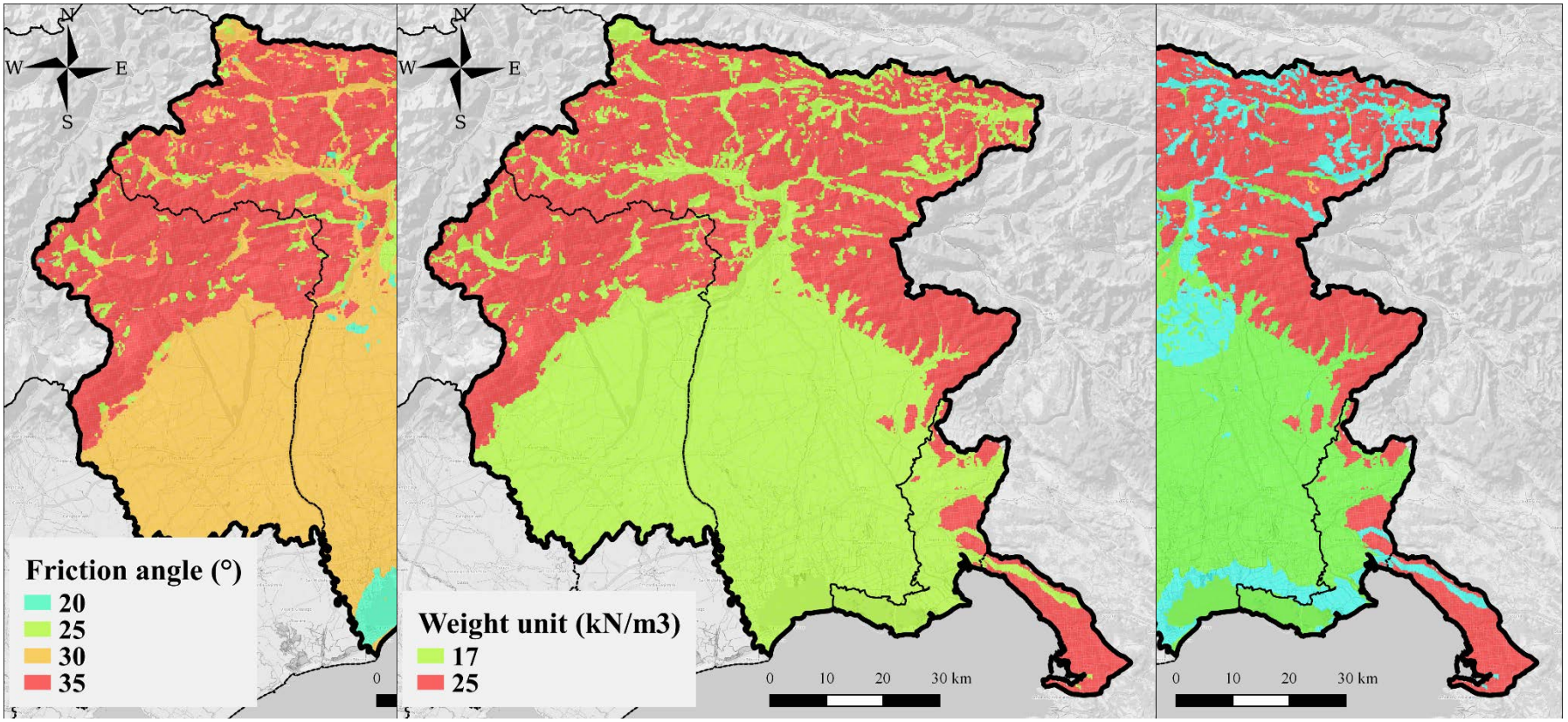
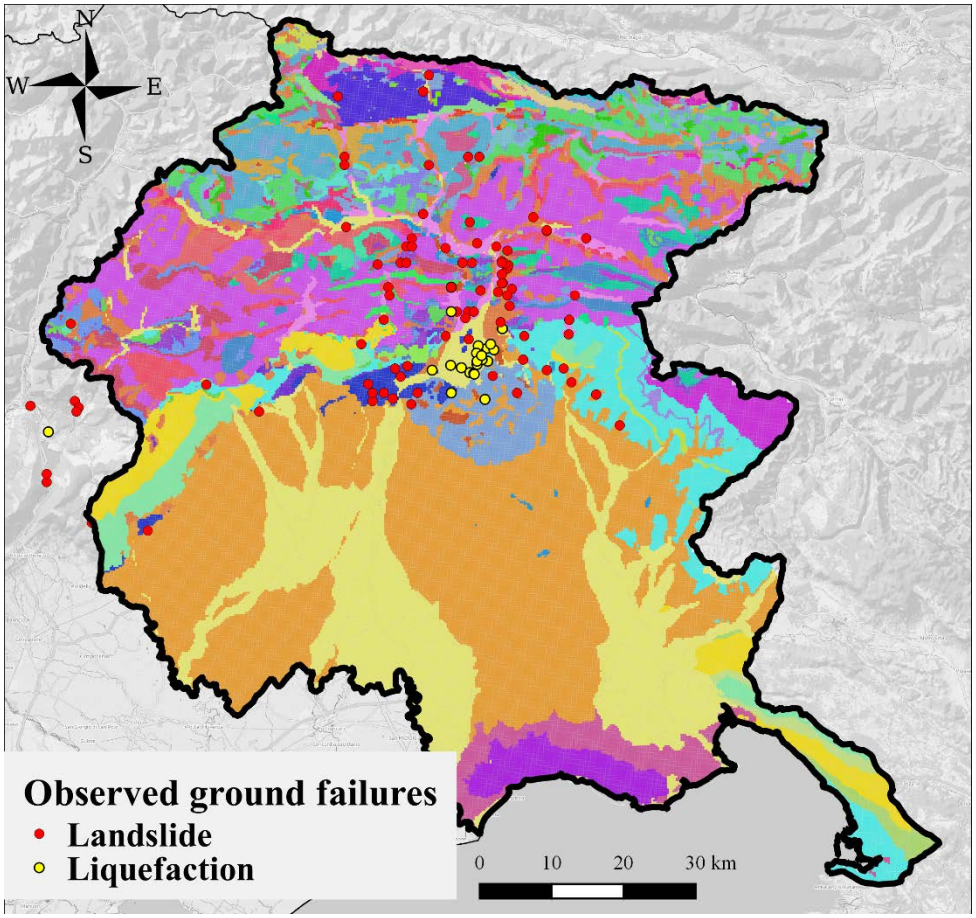


Case study: collected data

Historical observed ground failures

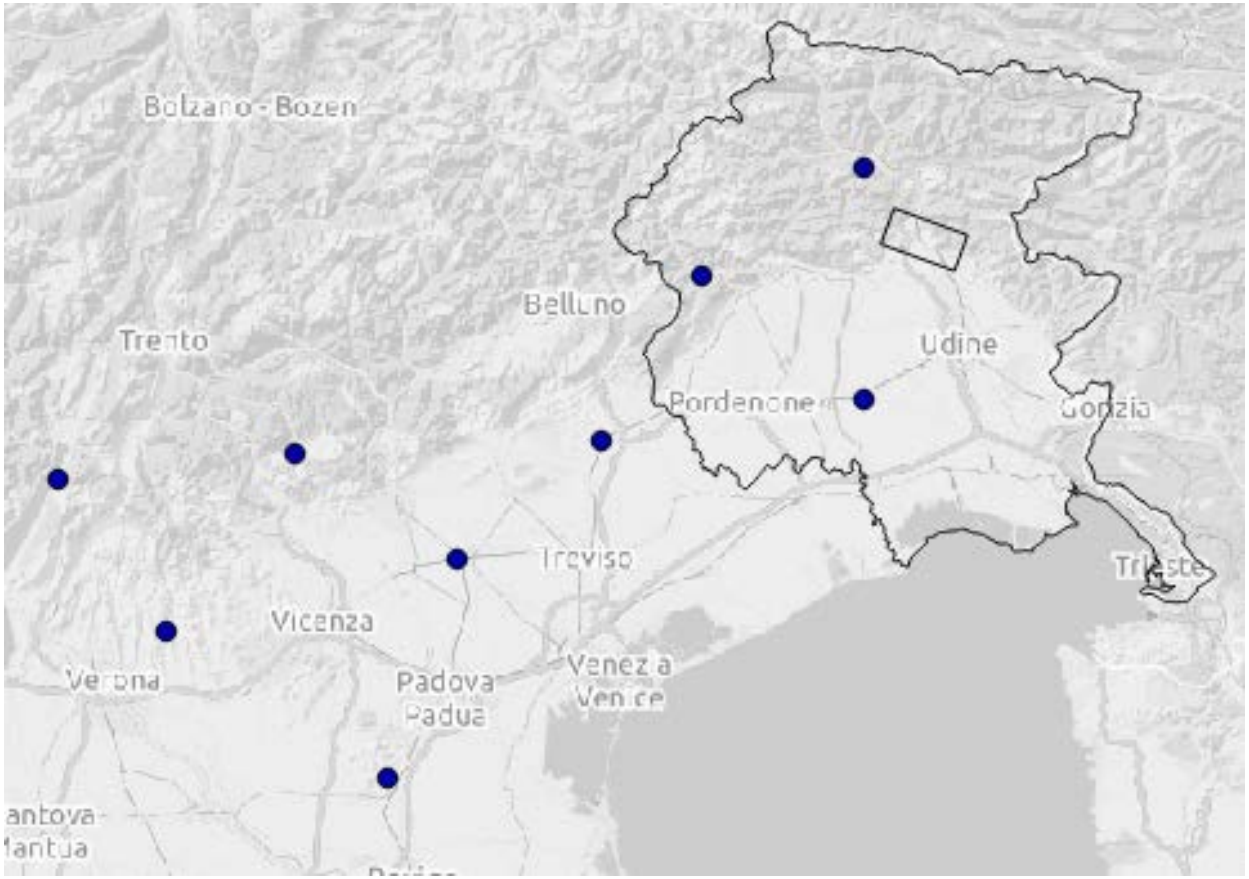
CEDIT database
Martino et. al 2014



Case study: collected data

Observations from seismic stations

Only 9 at that time



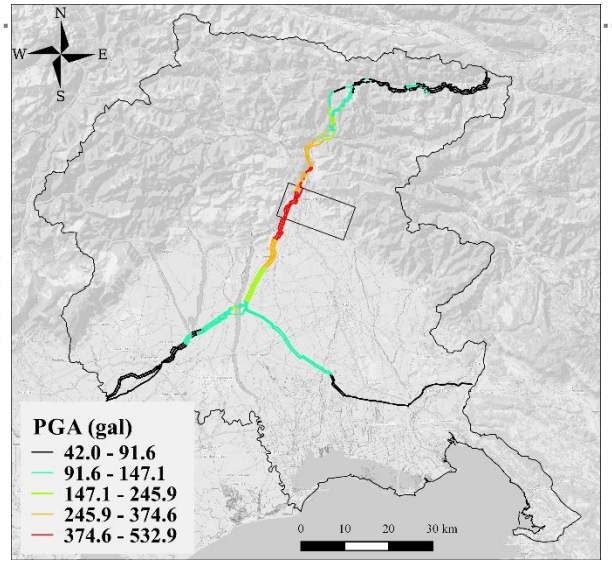
Case study: collected data

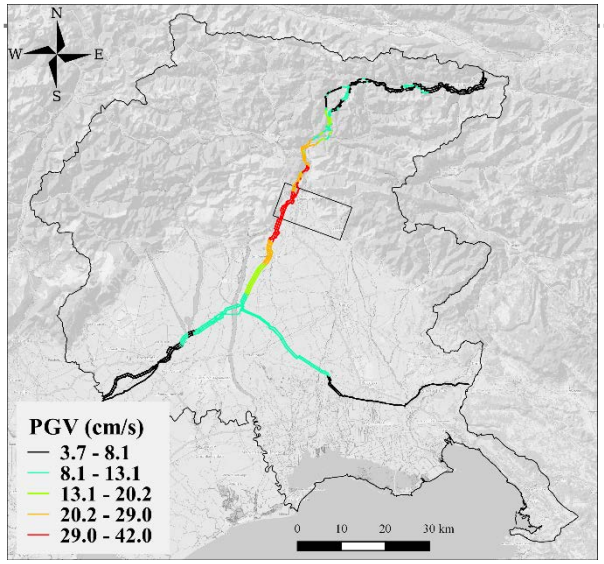
Observations from seismic stations

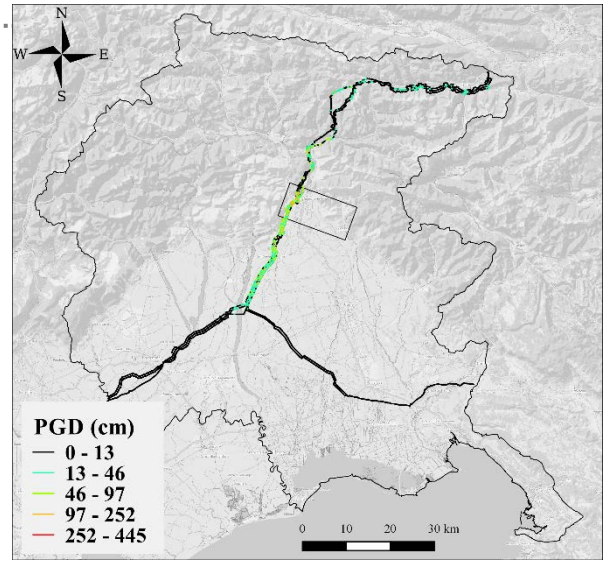
20 nowadays

Case study: 10^4 simulations

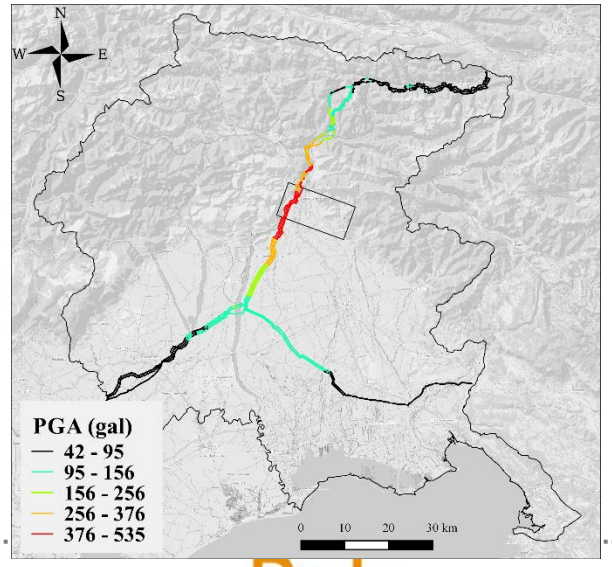
Case 1

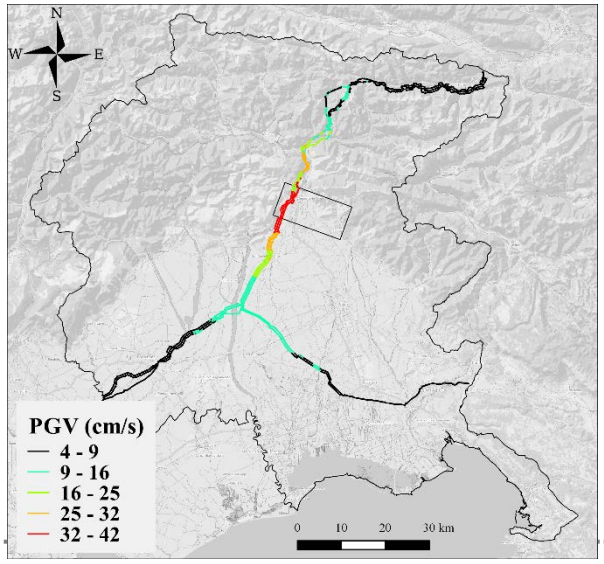


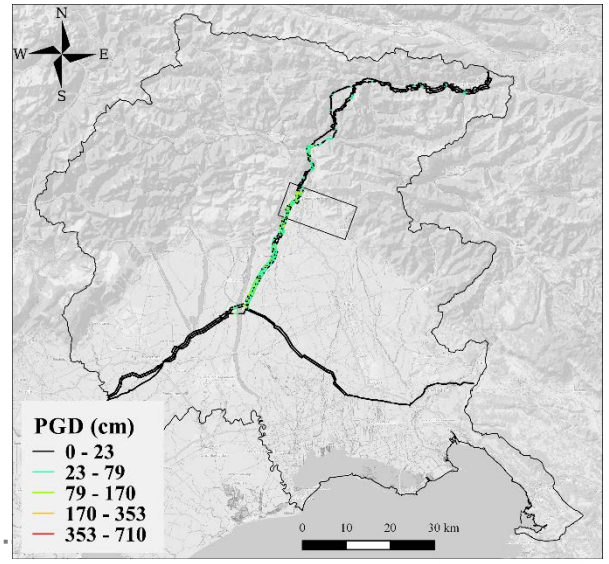




Case 5







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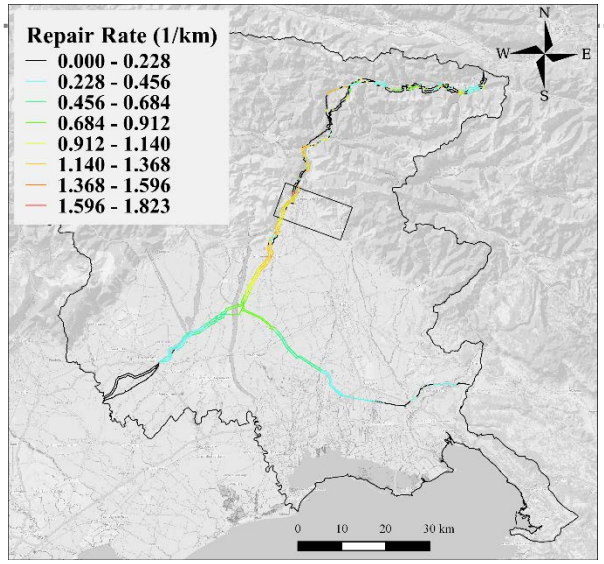
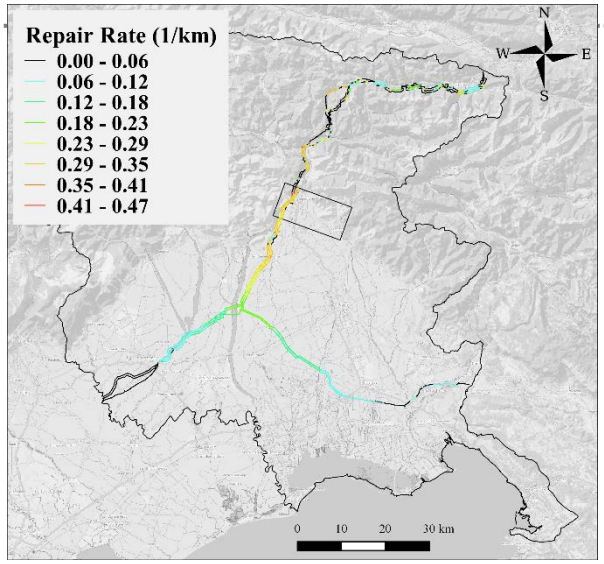
Repair Rate

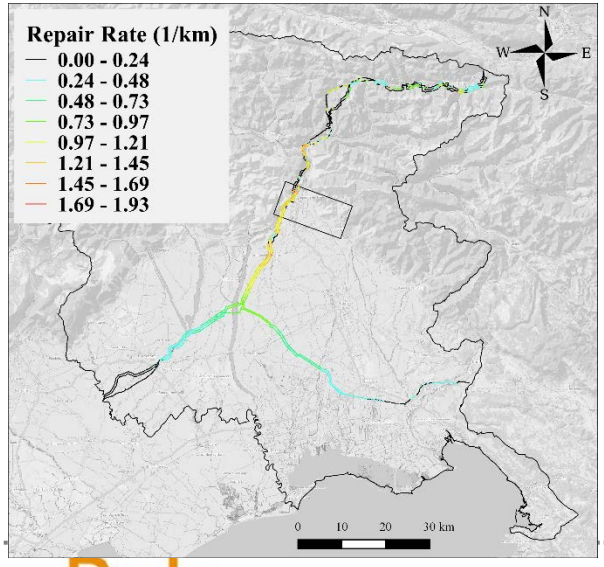
Break **Leak**

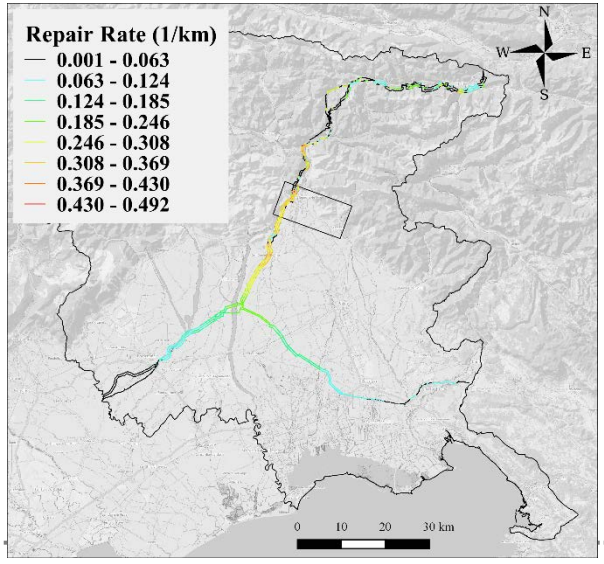
Case 1





Case 5





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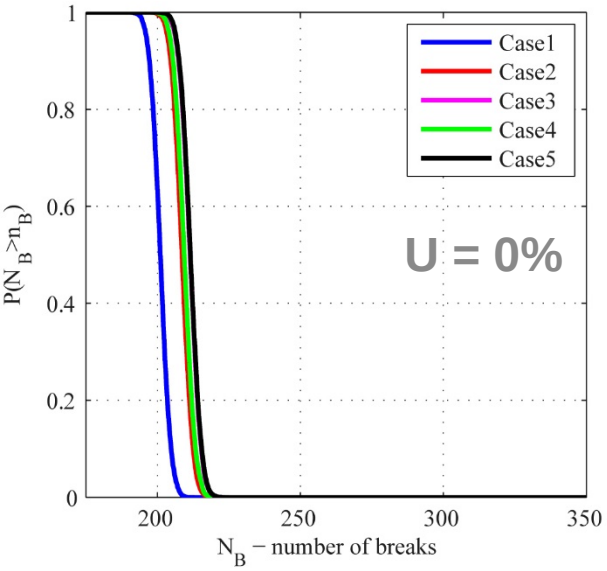
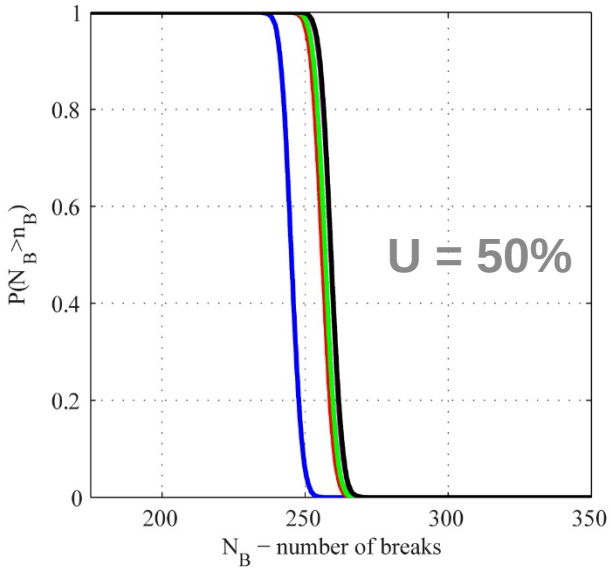
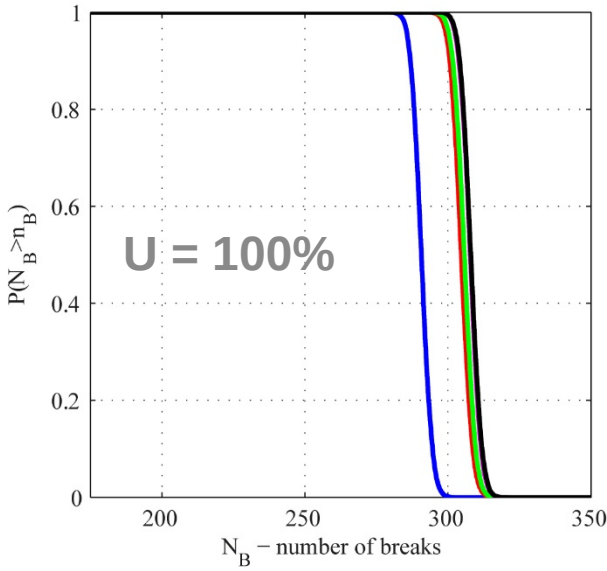
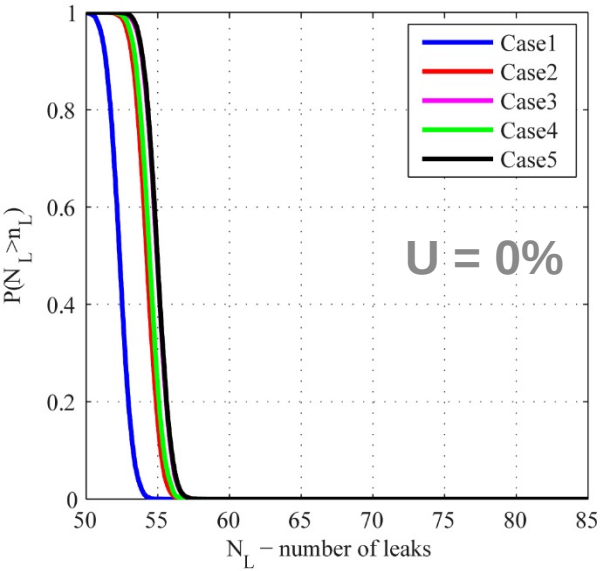
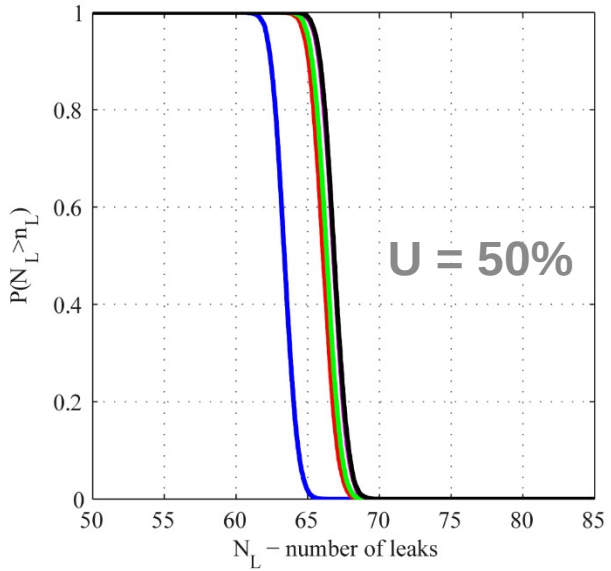
Repair Number for Breaks & Leaks

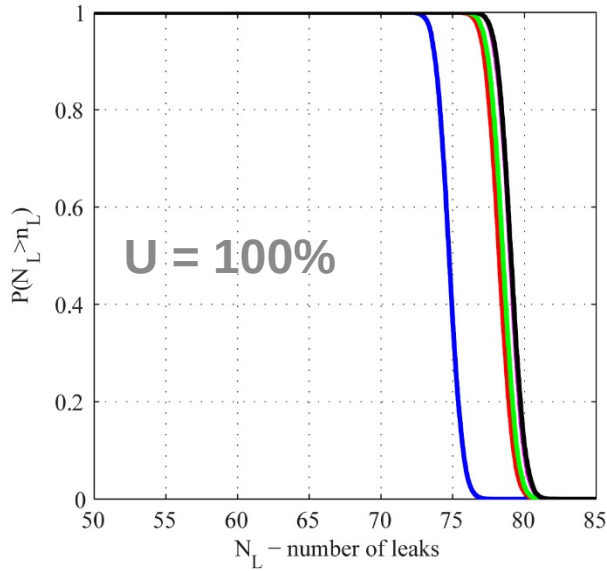












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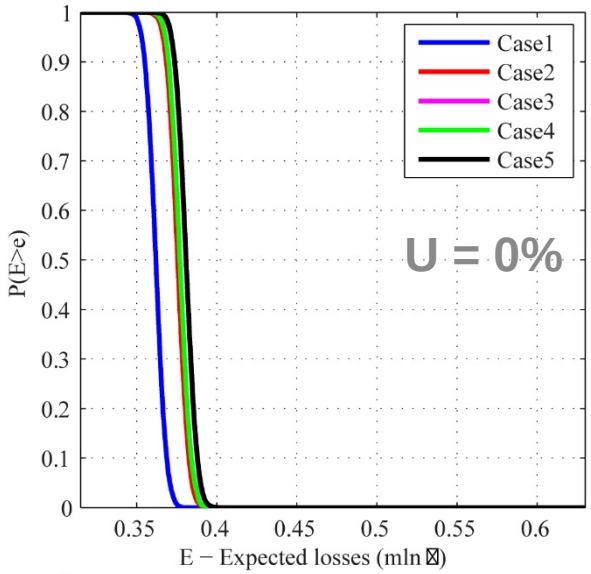
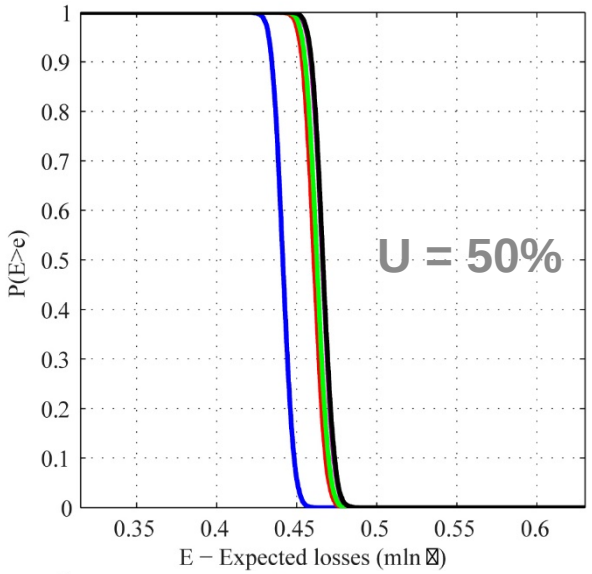
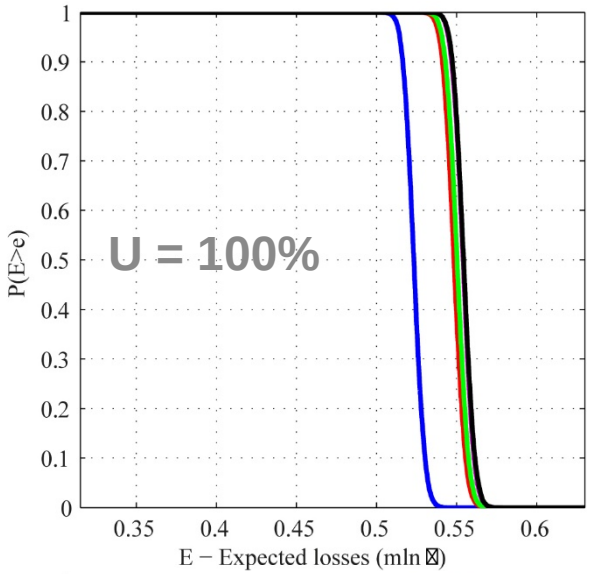
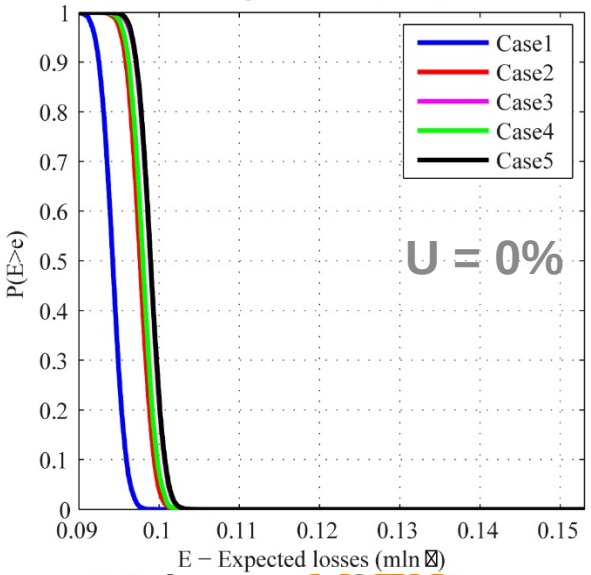
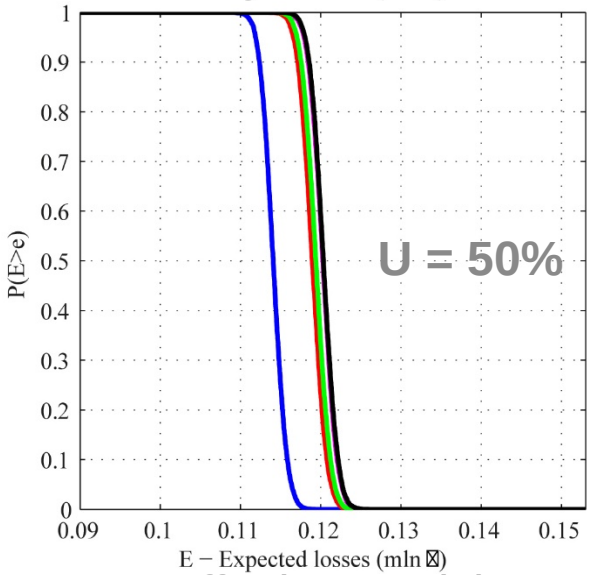
Repair Cost (NGP1 Hazus 1000$)

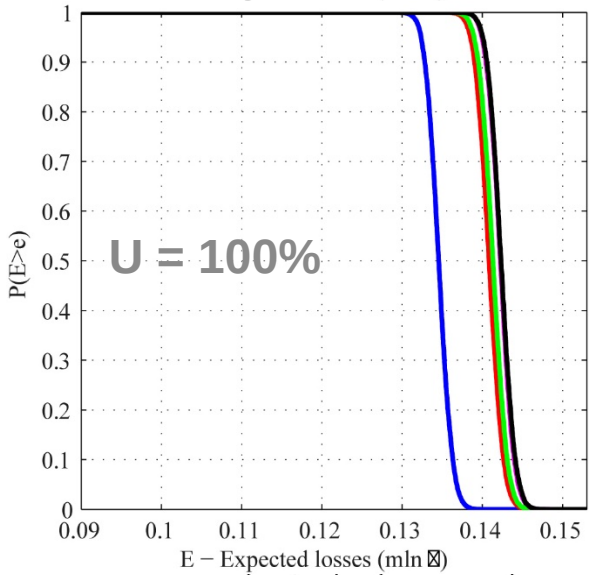






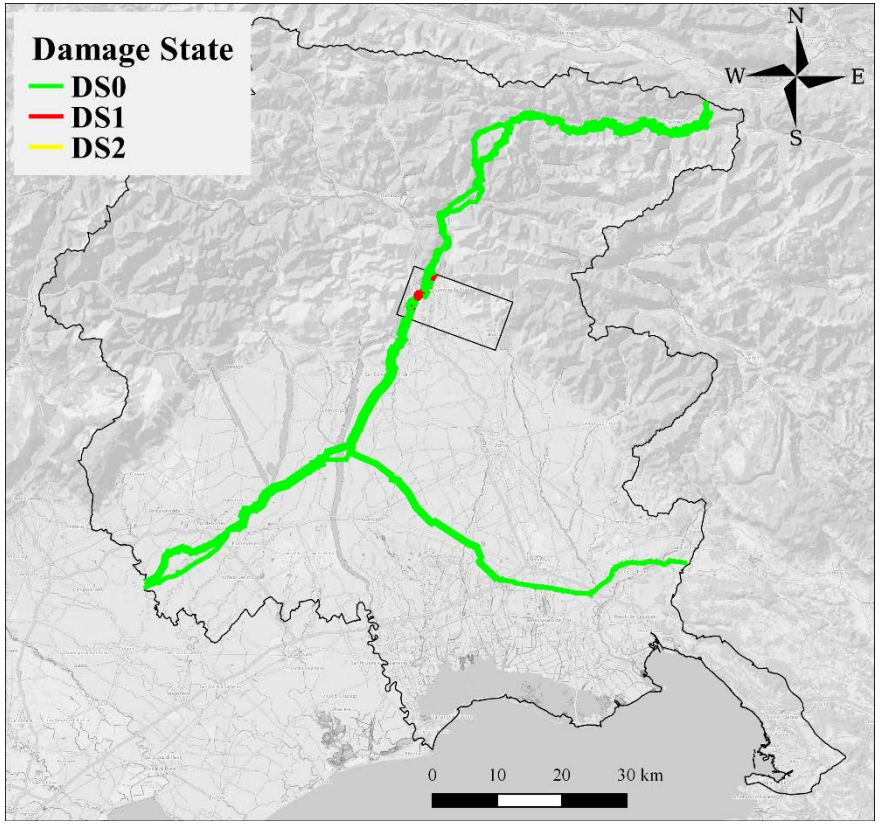




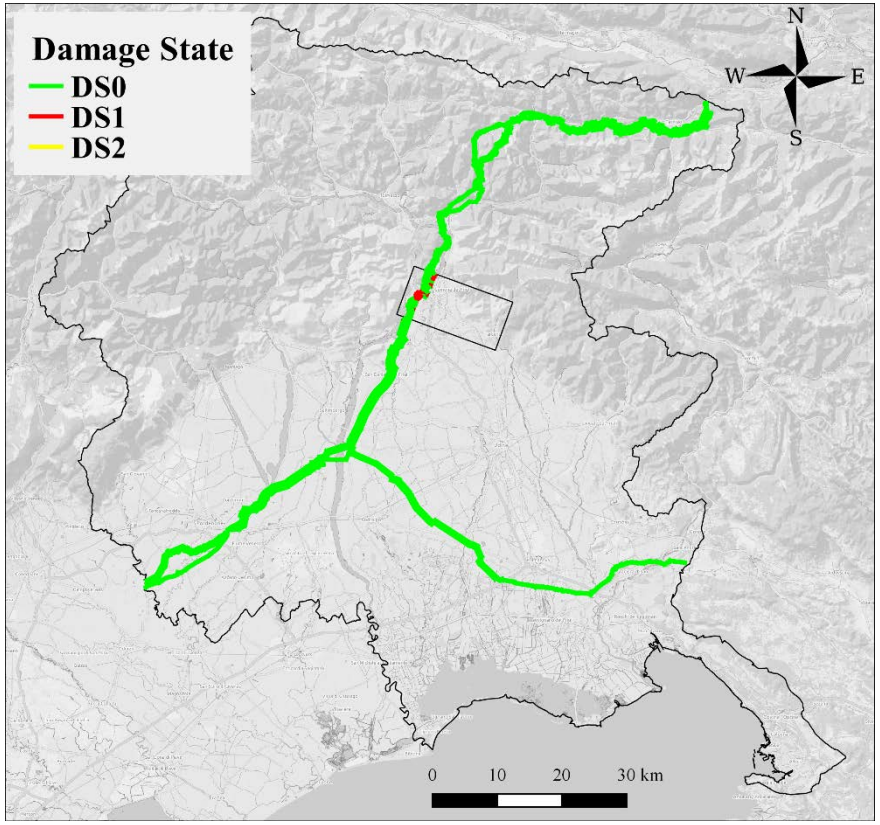


Using Fragility curves or ML

SGS Case1

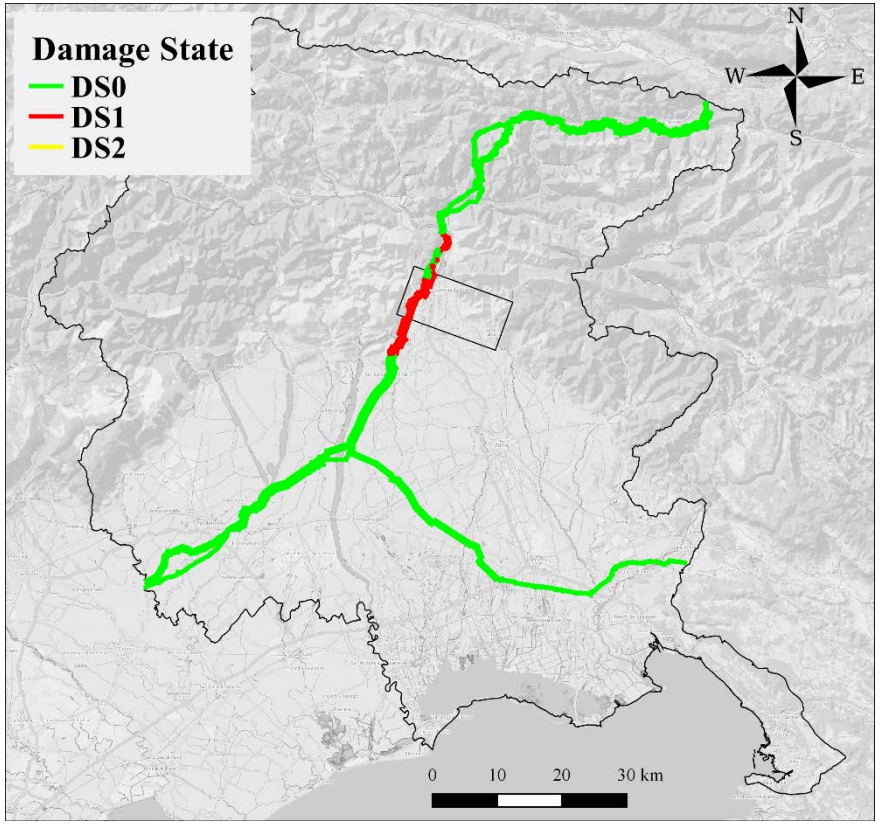


SGS Case5

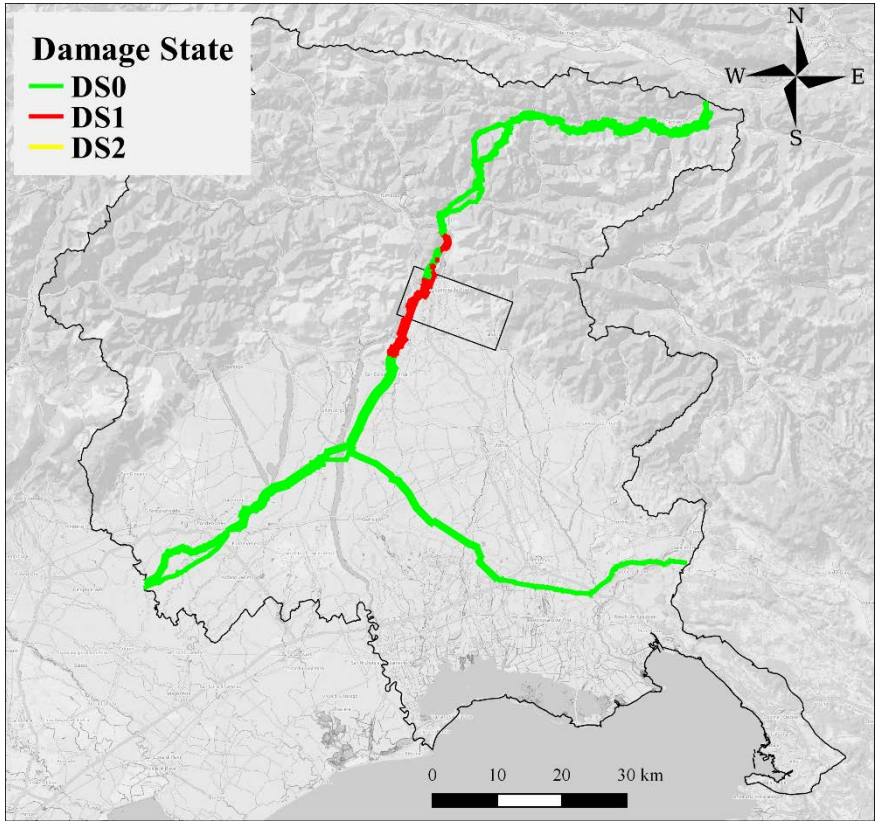


Using Fragility curves or ML

GF Case1



GF Case5



Conclusions and Future development

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- A potential development is the implementation of the coseismic displacement that have been neglected at this stage.

University of BRISTOL

Thank you for your attention!

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United Kingdom

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