UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

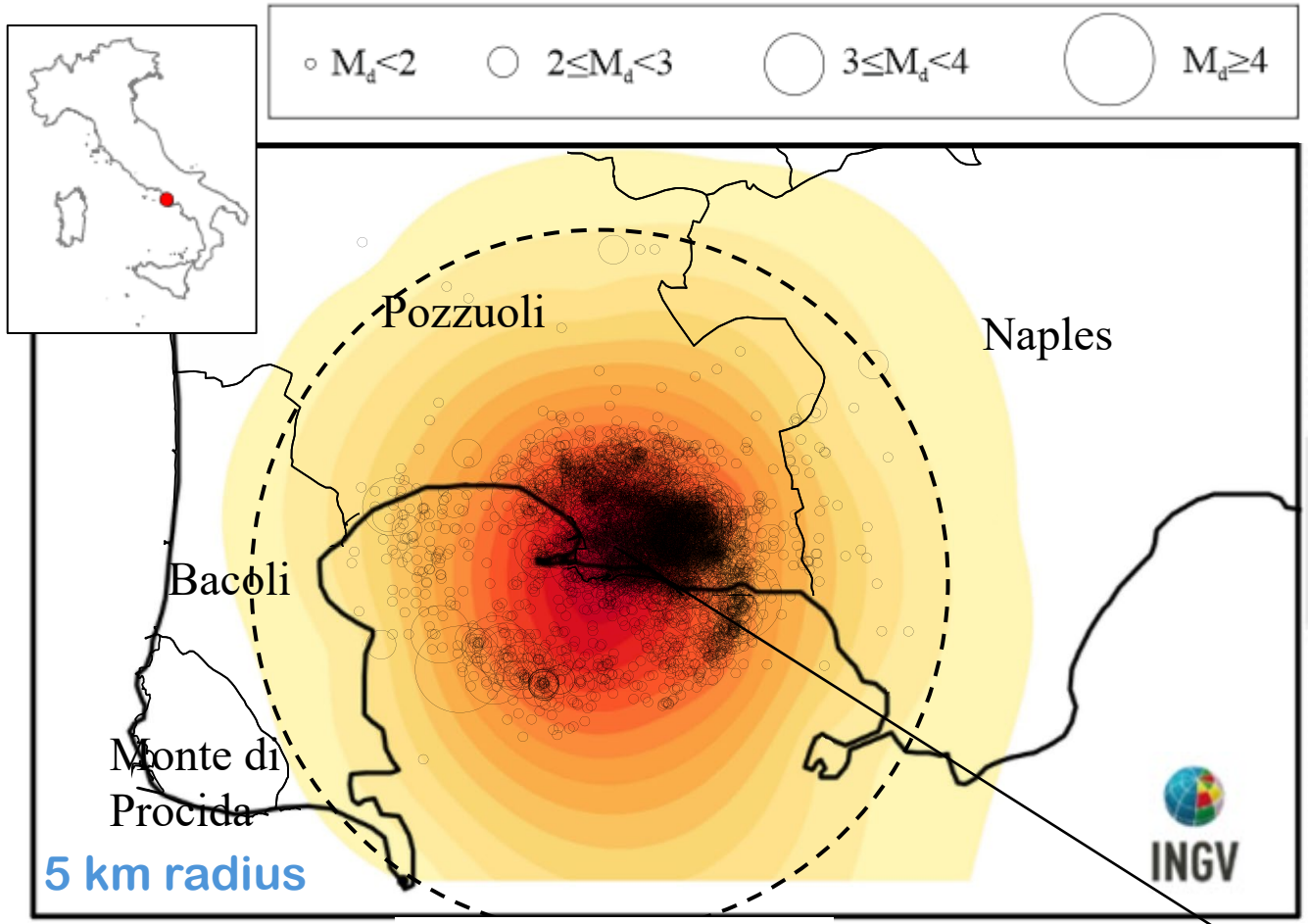
IUSS Scuola Universitaria Superiore Pavia

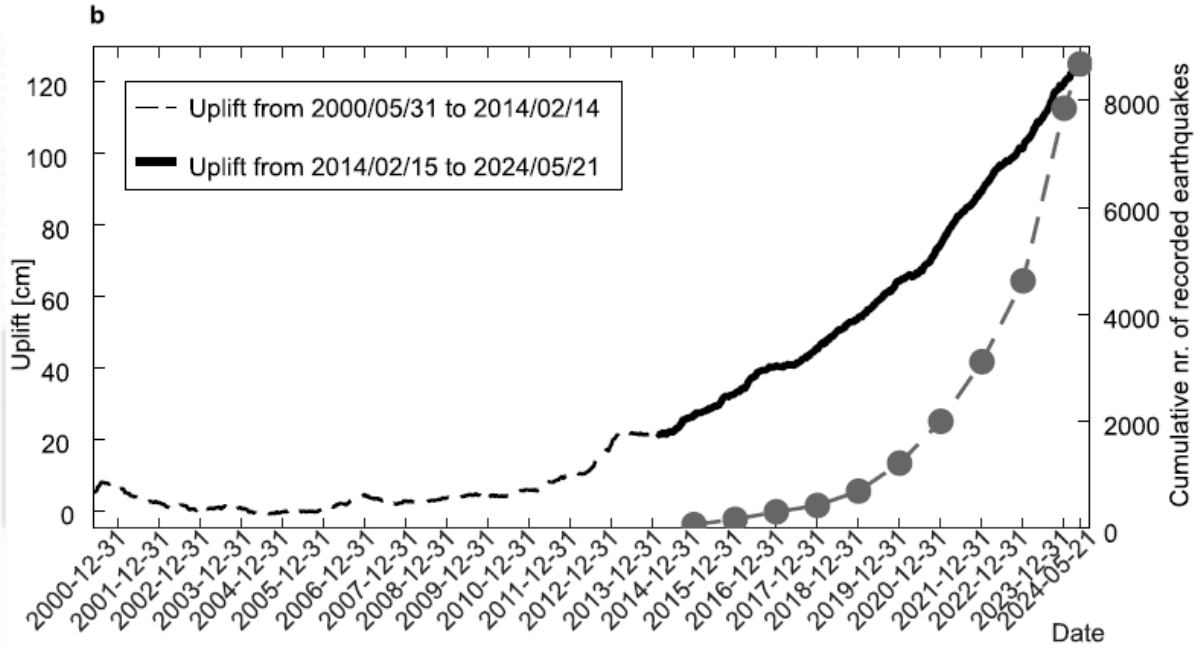
Bradyseism and earthquakes at Campi Flegrei (Italy)

Iunio Iervolino

Research group: **Pasquale Cito**, Roberto Baraschino, Melania De Falco, Gaetano Festa, Marcus Herrmann, Anthony Lomax, Warner Marzocchi, Antonio Santo, Claudio Strumia, Luigi Massaro, Antonio Scala, Francesco Scotto di Uccio and Aldo Zollo.

Davos 19/03/2025





About 130 cm since 2000

1. Degassing magma is uplifting a 5km radius area close to Naples, Campi Flegrei, no risk of impending eruption, yet seismic risk.
2. Earthquakes are of moderate-magnitude, yet shallow and rich in high-frequency, causing seismic actions that are non-negligible at epicentral distances lower than 1 km (fast attenuation).
3. The local government asked:
    1. Maximum magnitudes possible. We found reference magnitudes in the range (4.4-5.1).
    2. Whether upgrading of existing building to the standards of new construction would be a feasible mitigation strategy. We found that:

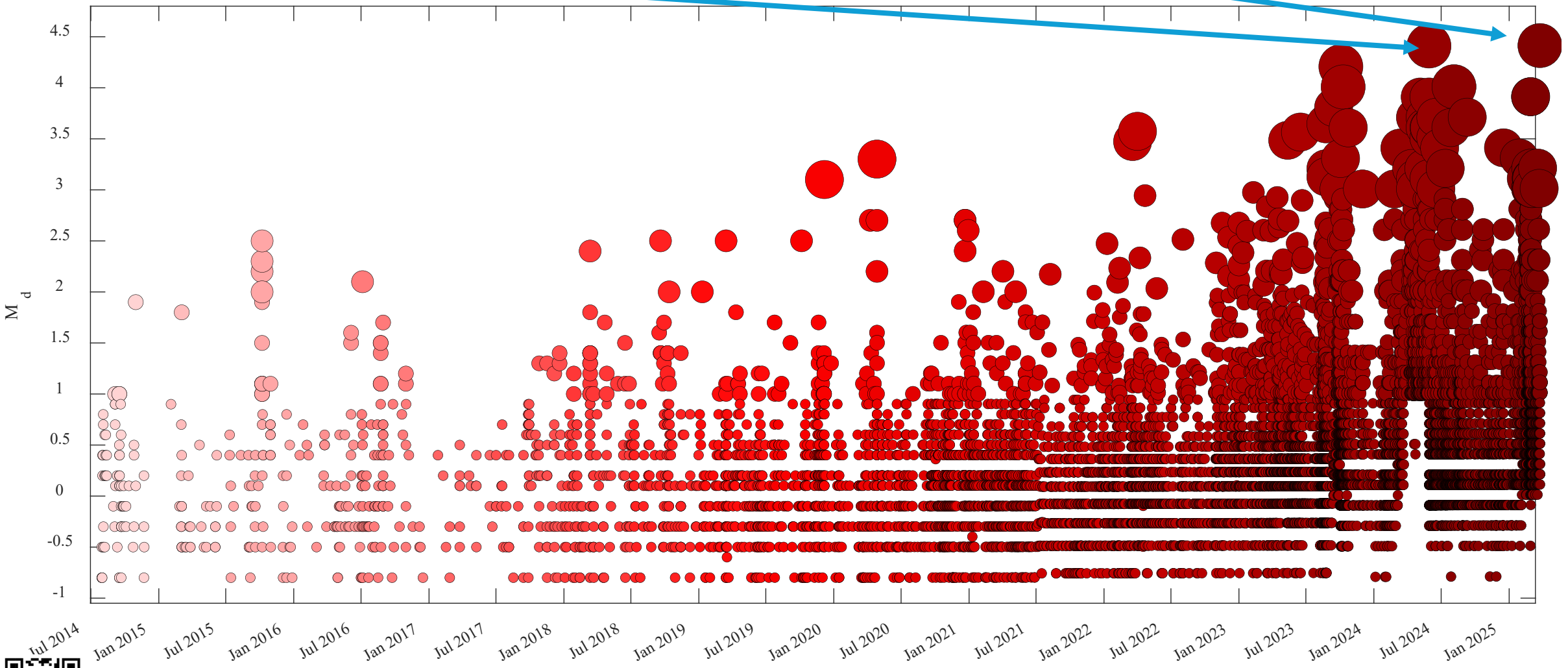
a. Minimum magnitudes causing exceedance of ground motion larger than design requirements of new construction are generally larger than reference magnitudes.

b. New contractions have fatality rates at least 70% lower than existing buildings in the area.

About 12,000 events in the last decade with M_d>-1.1.

M_d4.4 20/05/2024 - M_w4

M_d4.4 (4.6) 13/03/2025 - M_w4



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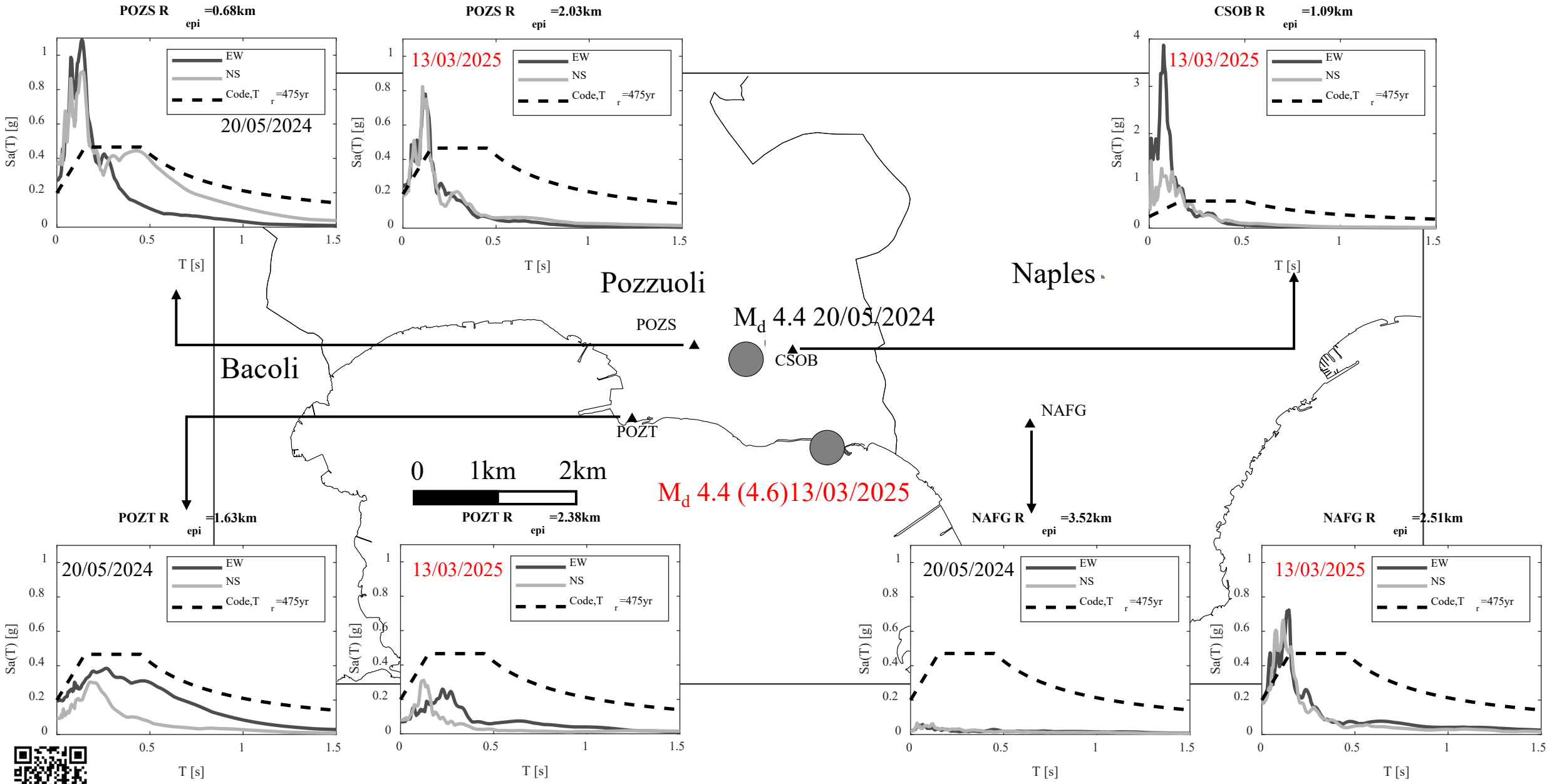

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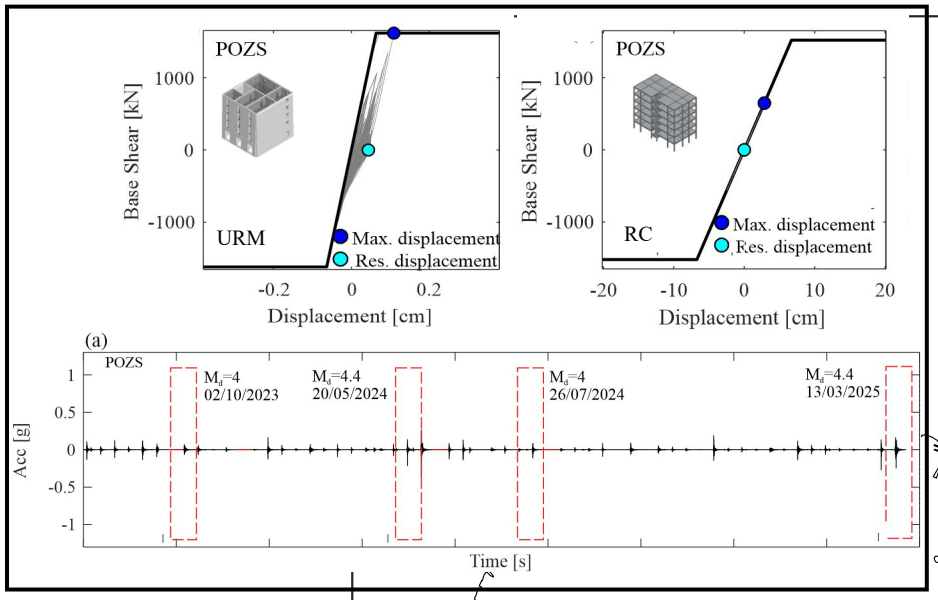
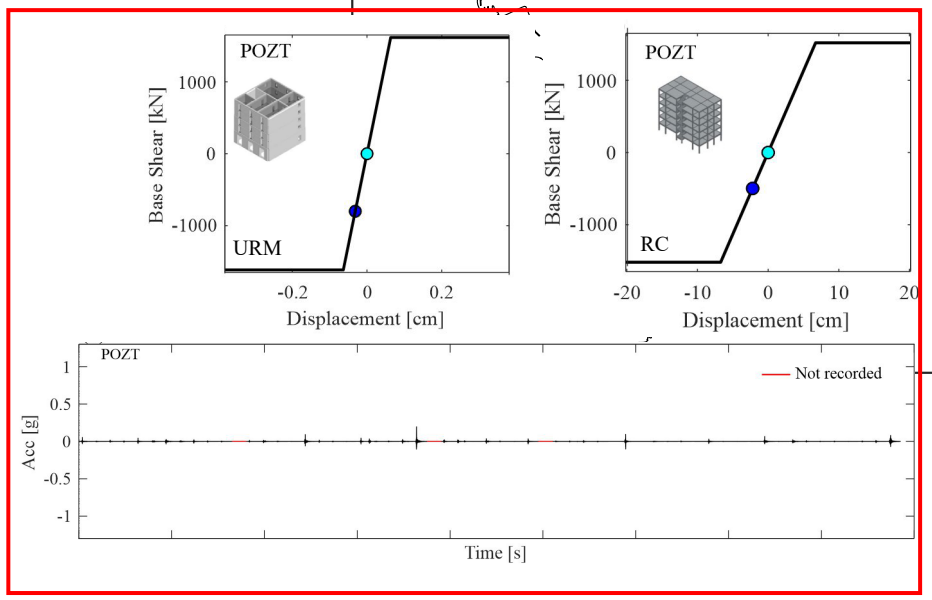
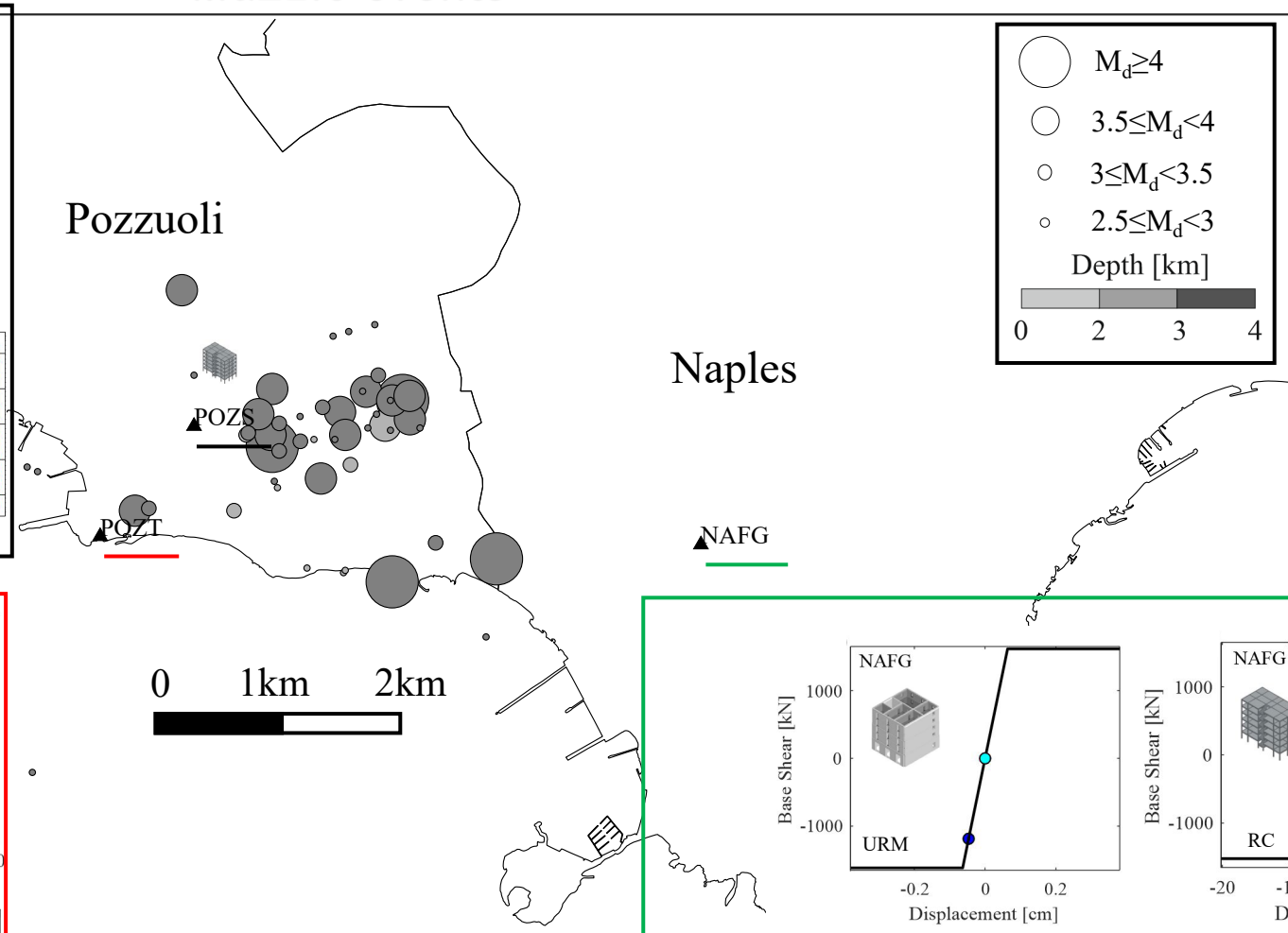
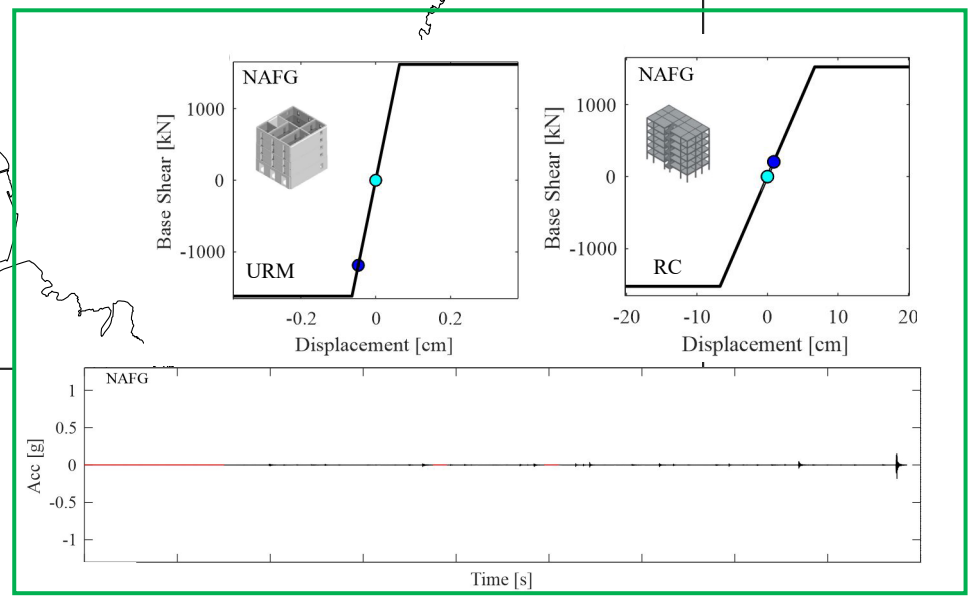
Md≥2.5 events

EESD



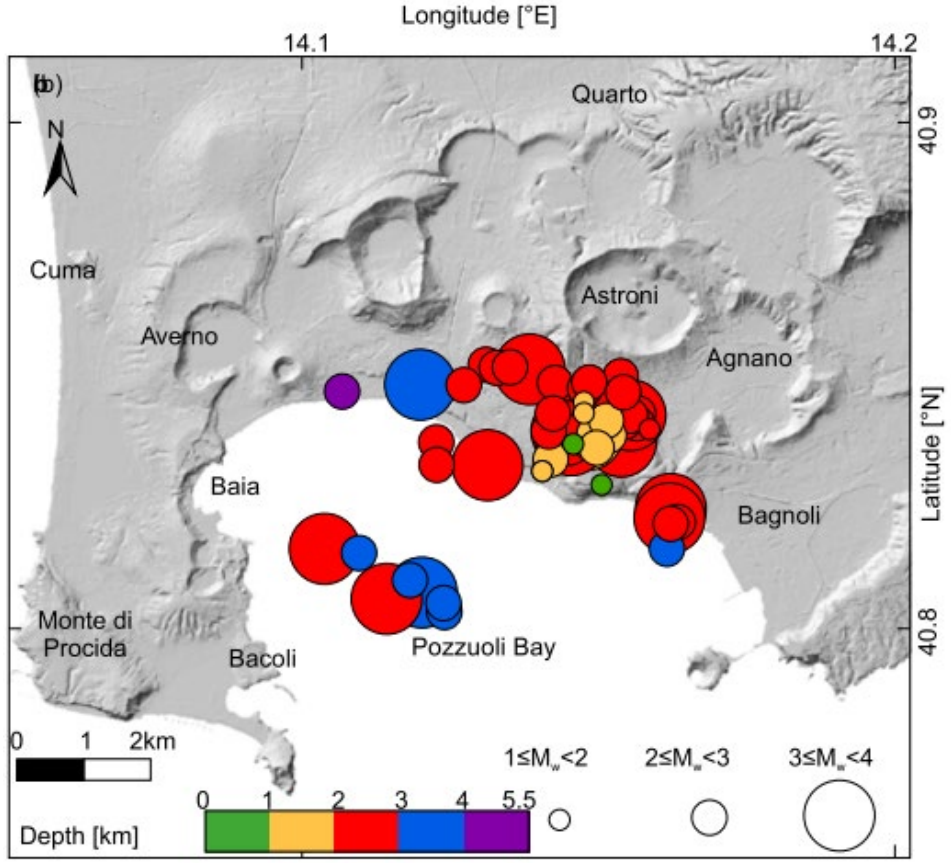


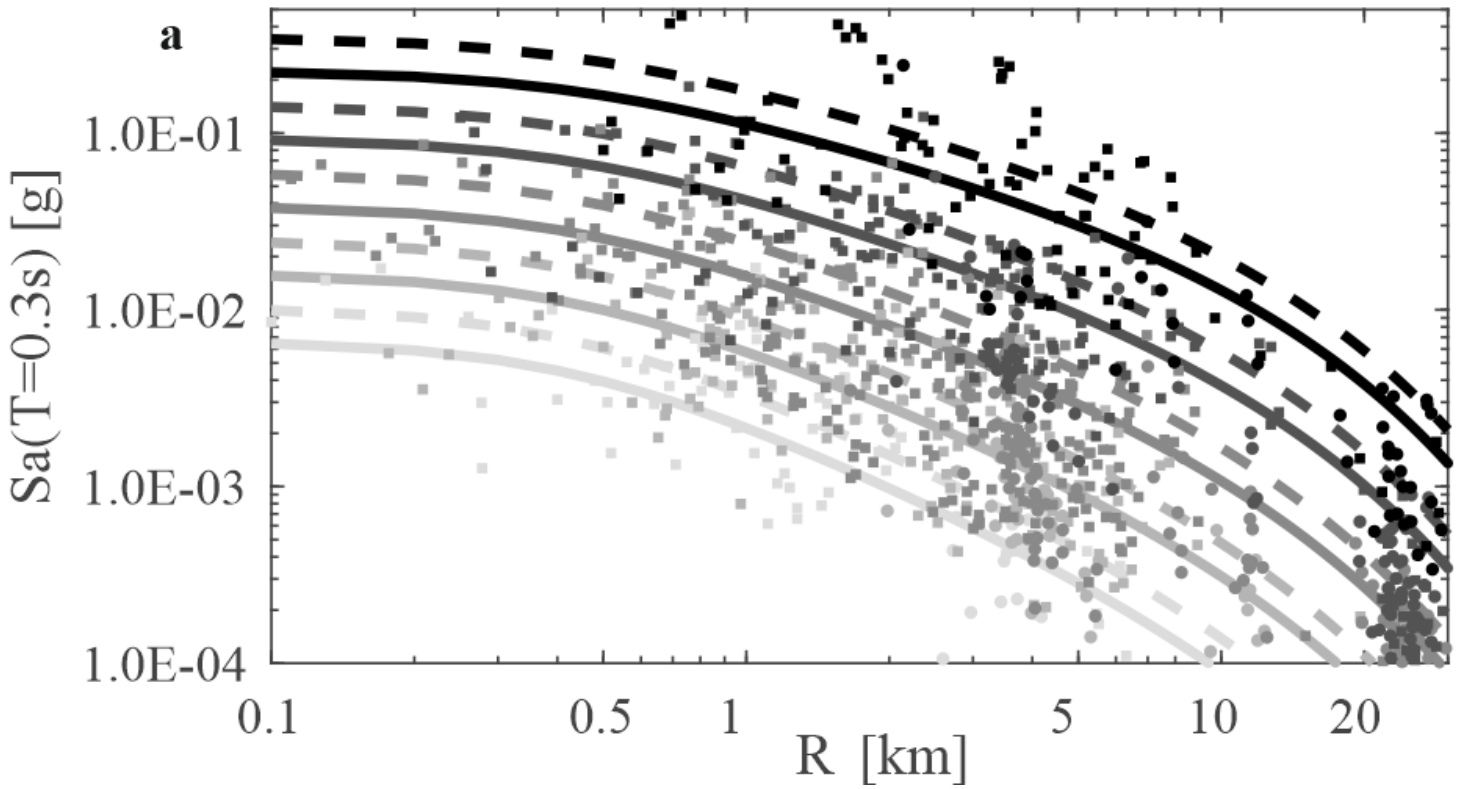




Md≥2.5 events

$$\log_{10}[Sa(T)] = a + b \cdot M_w + (c + c_2 \cdot M_w) \cdot \log_{10}\left(\sqrt{R^2 + h^2}\right) + c_3 \cdot \sqrt{R^2 + h^2} + e \cdot S \pm \gamma.$$





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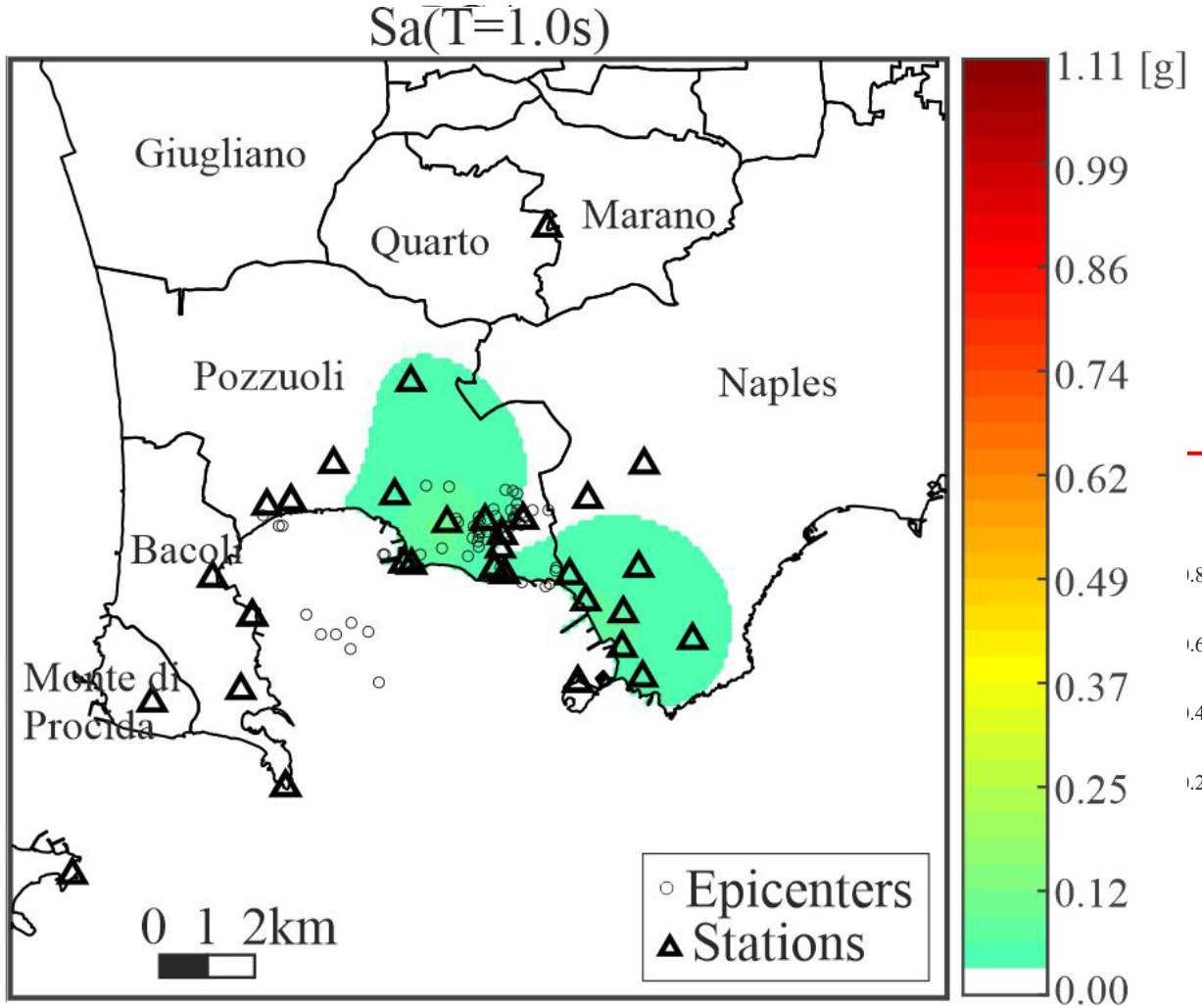
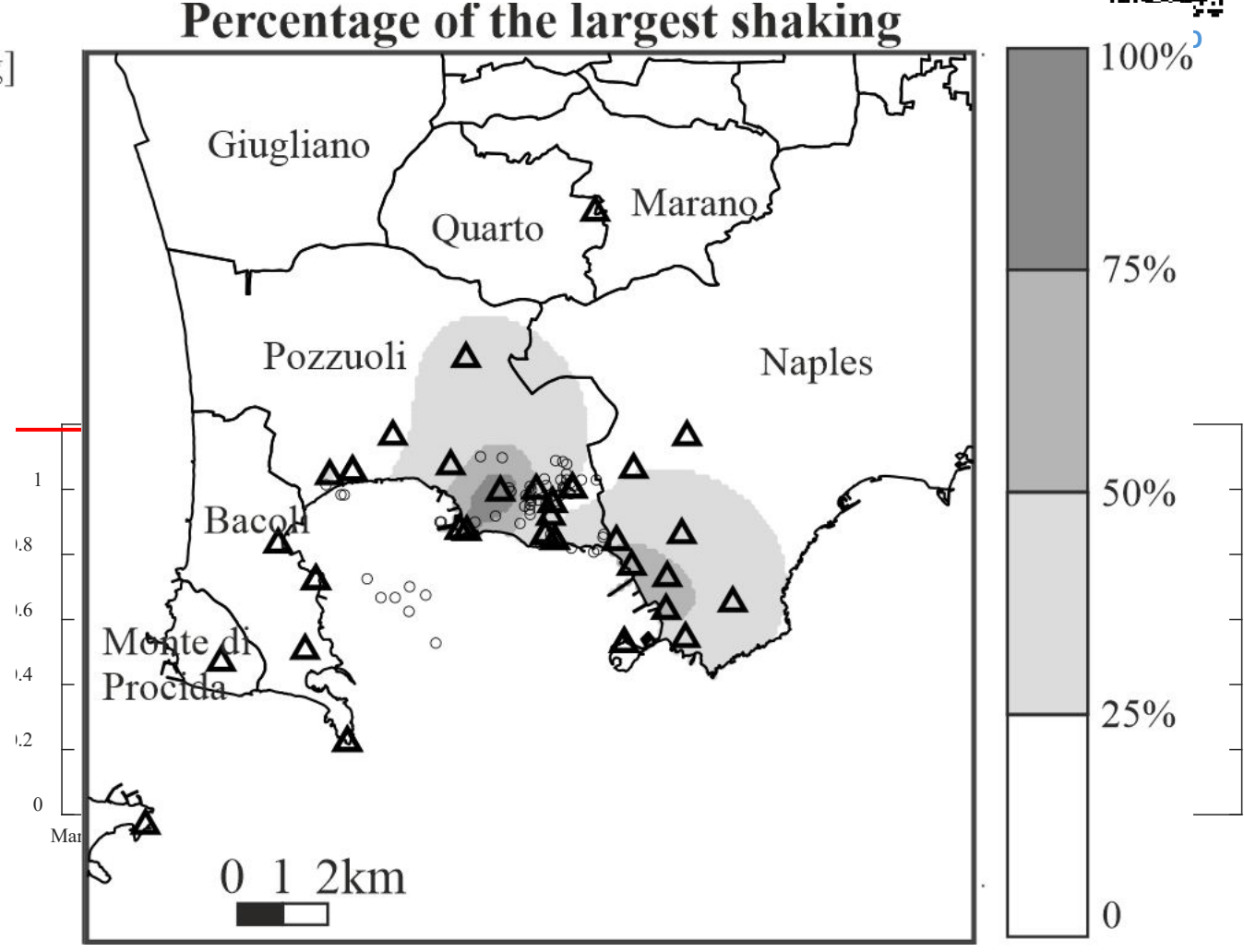
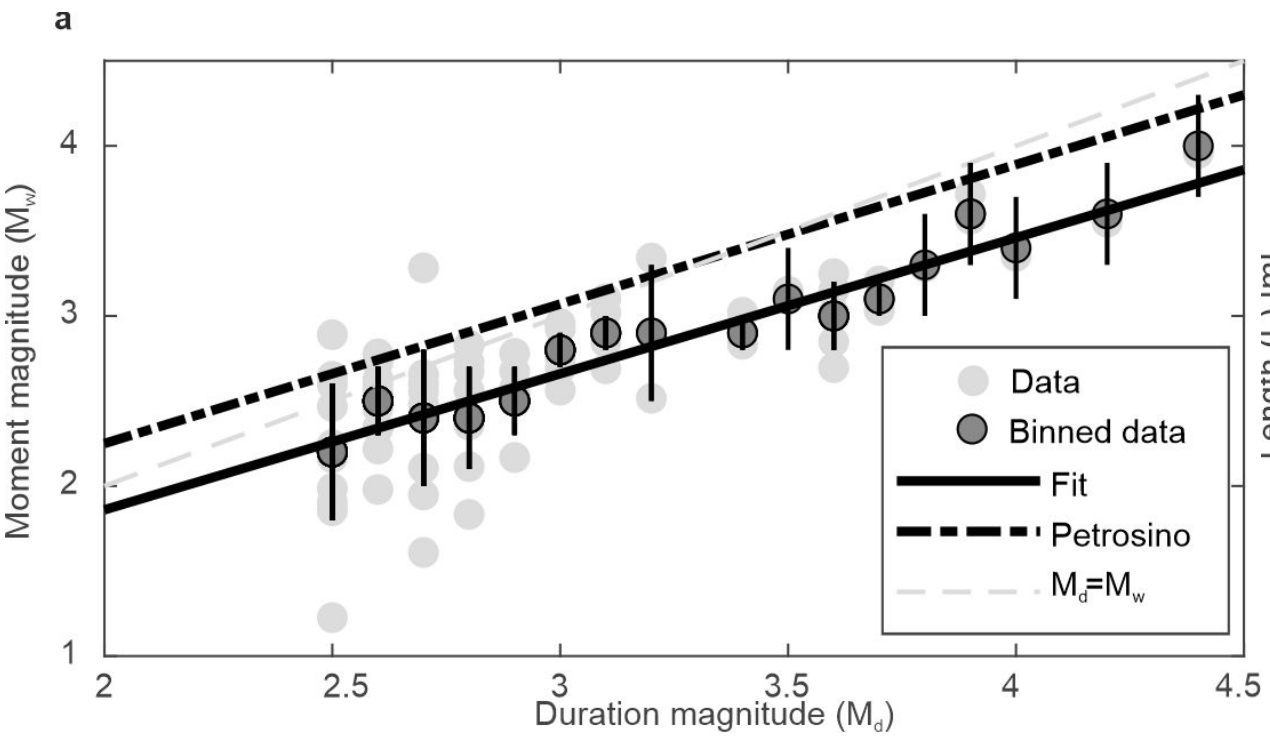
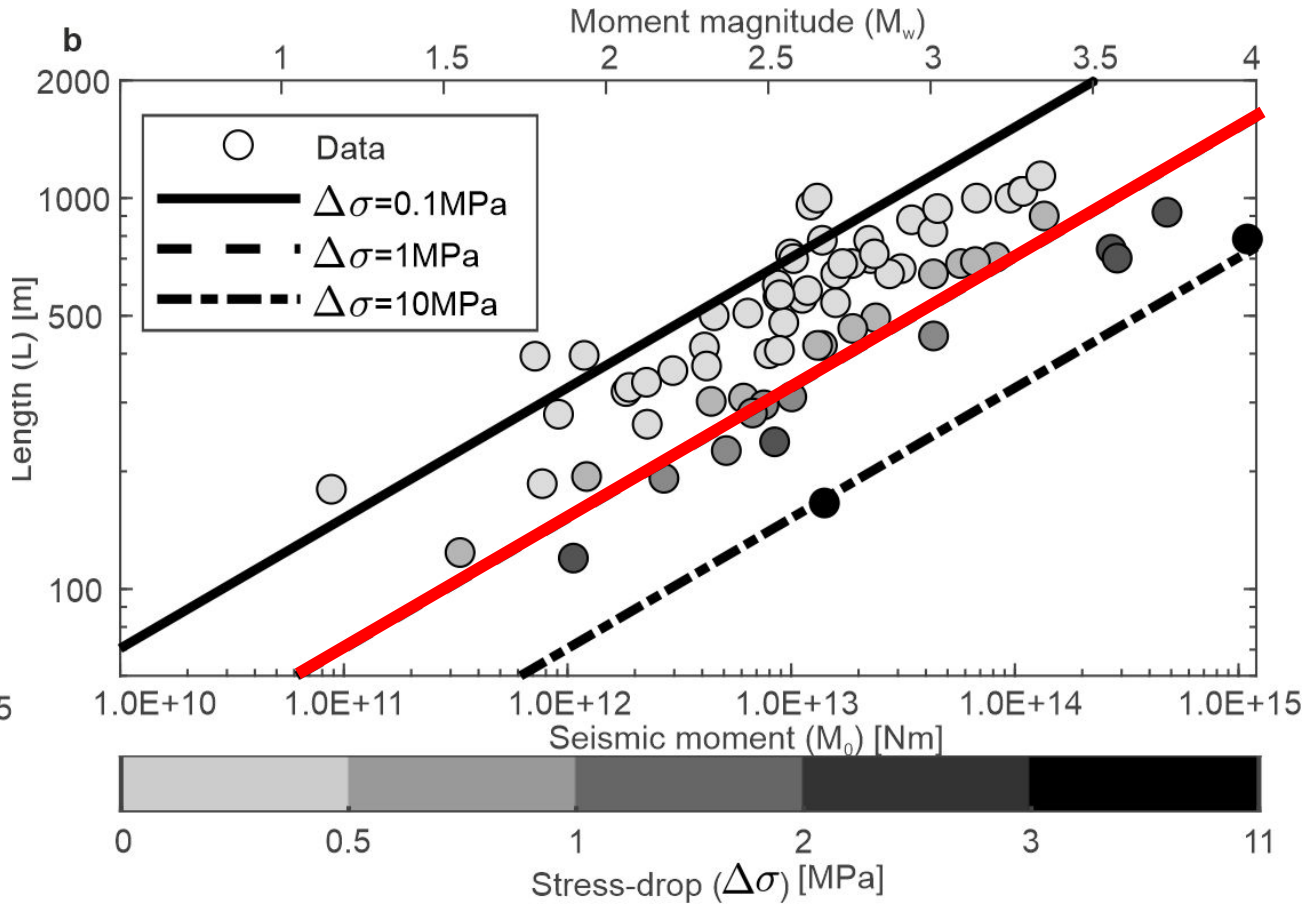
Shakemap envelopes









M_w - M_d **relationship:** $M_w = 0.8 \cdot M_d + 0.26$

L - M_w **relationship** $M_w = 2 \cdot log(L) - 2.42$

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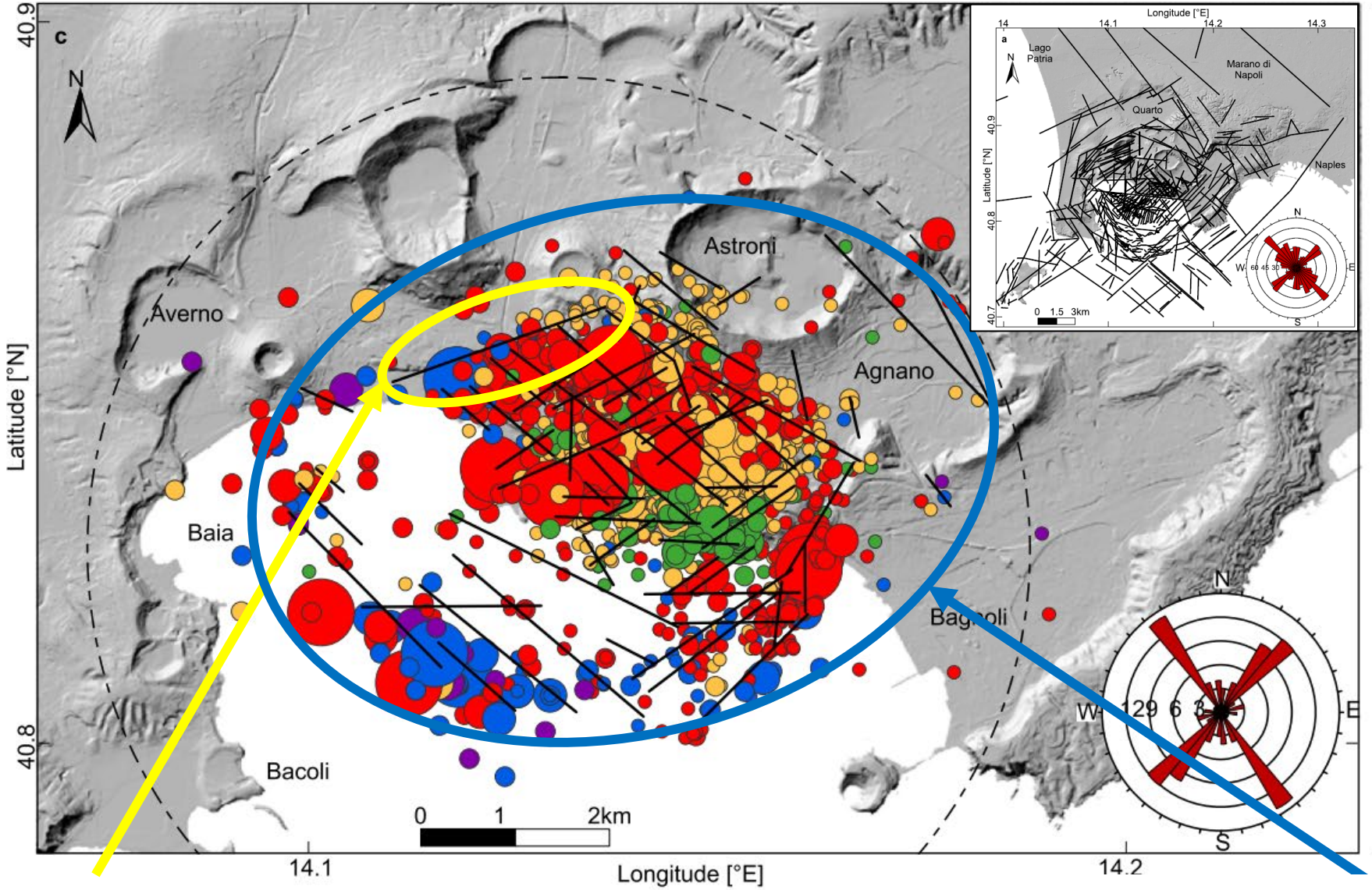

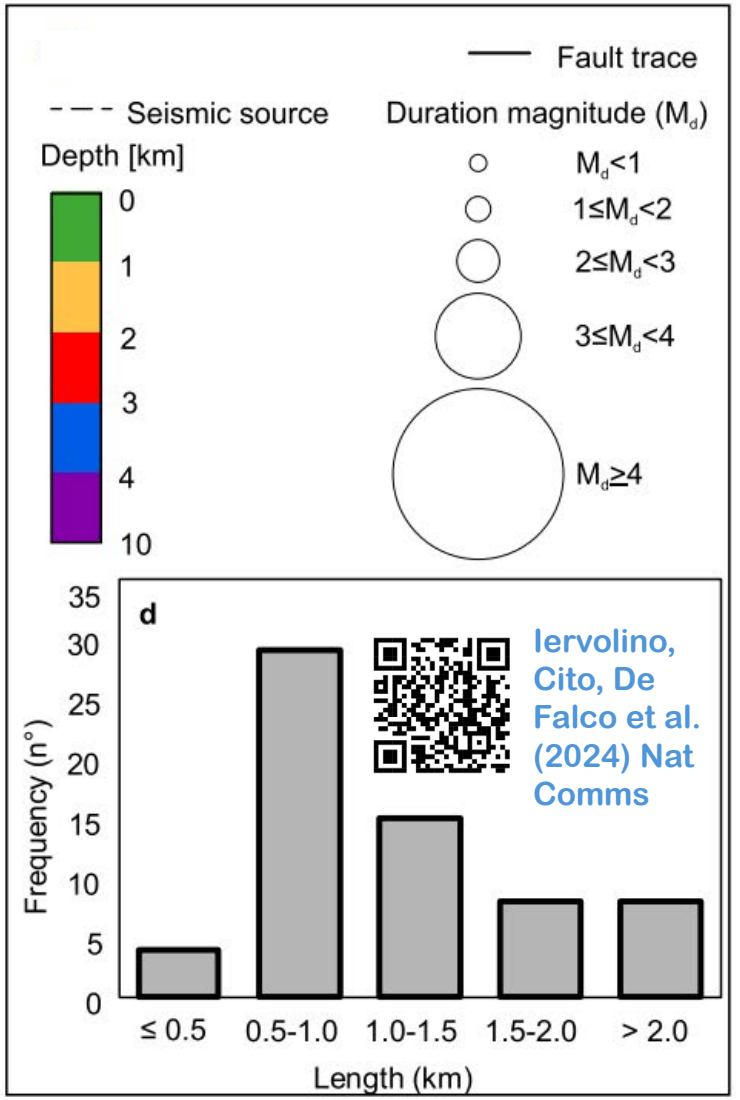

M_w associated with longest (about 2.7km) fault: 4.4.

M_w associated with multiple faults activation: 5.1

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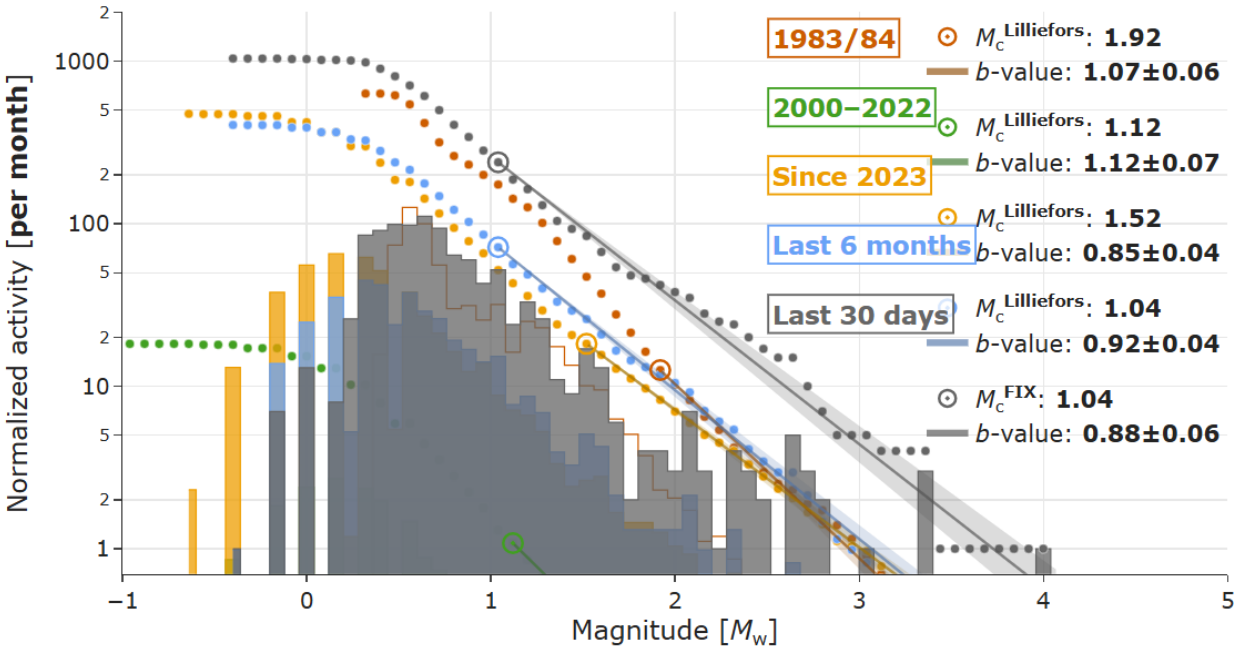
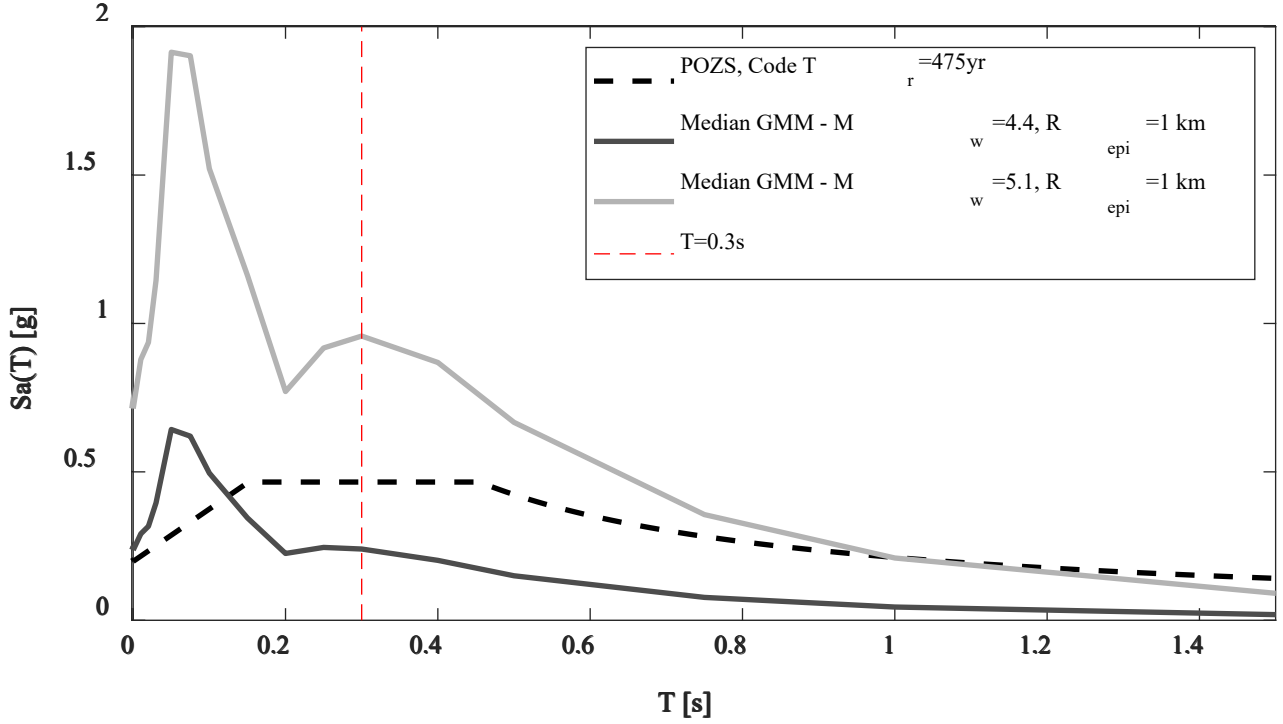
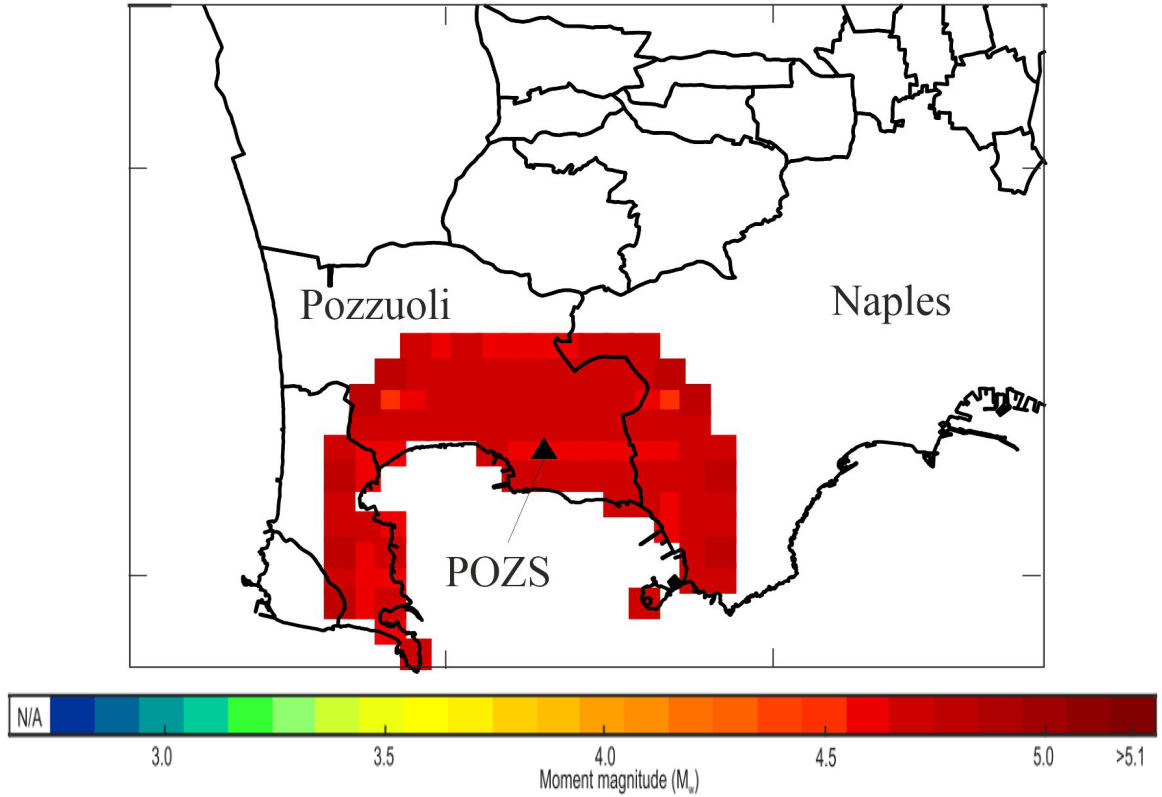
Operational earthquake forecasting



M_w	Probability of exceedance in the month following 18 March 2025 (range)
4.4	<0.001-0.2
5.1	<0.001-0.06

Strong earthquakes





$$M_{w,Sa(T)>sa_{T_r}|R\leq z} = \underset{m}{\operatorname{argmin}}\left\{\int_{r_{min}}^{r_{max}} P\left[Sa(T) > sa_{T_r}|M_w = m, R = r\right]\cdot f_{R|R\leq z}(r)\cdot dr > 0.5\right\}$$

AoG

Design intensity	$sa_{T_r}(T = 0s)$, or PGA	$sa_{T_r}(T = 0.3s)$	$sa_{T_r}(T = 1.0s)$	$sa_{T_r}(T = 1.5s)$
Full	5.0	5.1	5.1	> 5.1
Reduced by 20%	4.9	5.0	5.1	> 5.1
Reduced by 40%	4.7	4.8	5.0	5.1

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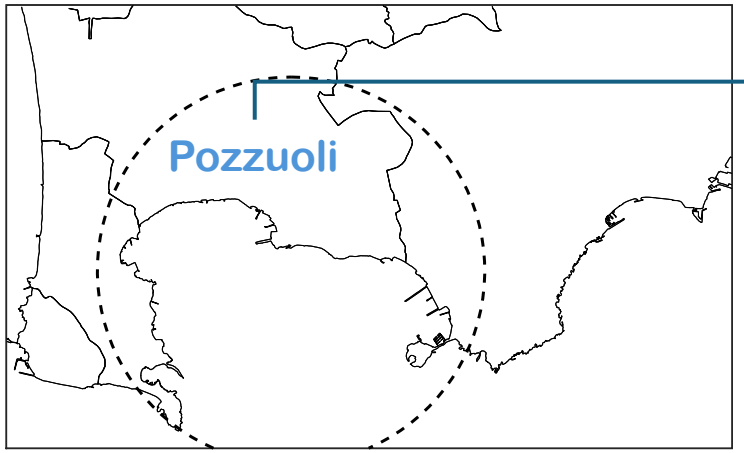
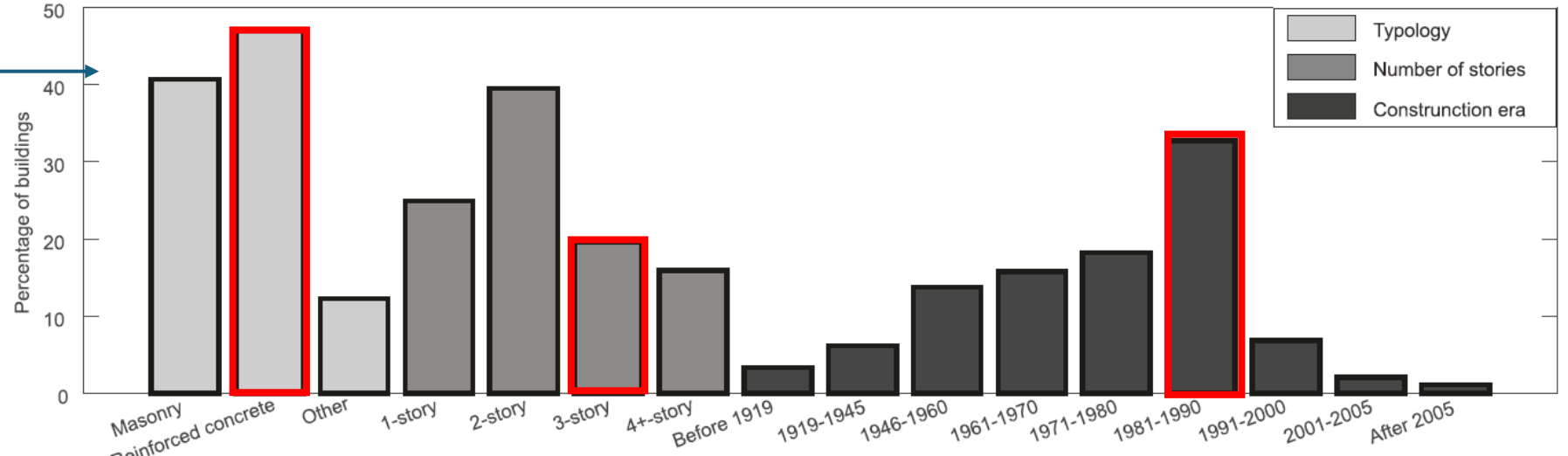
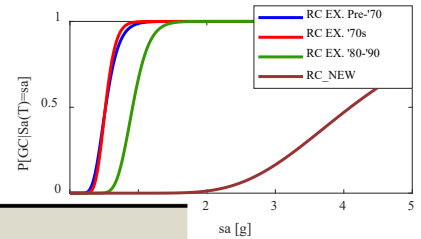
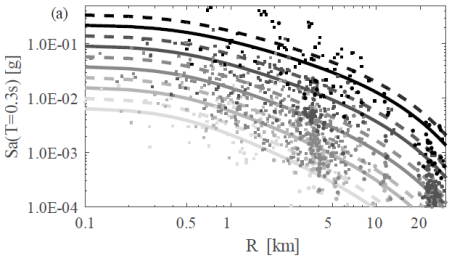
Building stock in Pozzuoli

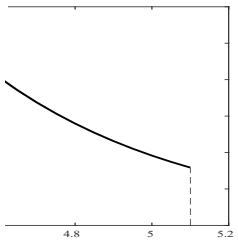


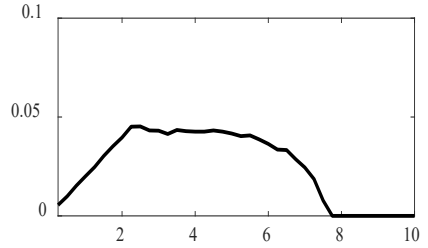


$$\frac{\lambda_{death,new}}{\lambda_{death,existing}} = \frac{\int_0^{+\infty} P[Collapse|IM=im]_{new} \cdot f_{IM}(im) \cdot d(im)}{\int_0^{+\infty} P[Collapse|IM=im]_{existing} \cdot f_{IM}(im) \cdot d(im)}$$









Description	Fatality rate reduction		
3-st RC building designed according to 80s–90s standards	λ_d (RC_IF_3_NTC18)/(λ_d (RC_IF_3_80–90)	M_w>1.5	0.31
		M_w>4.4	0.29
		M_w>5.1	0.21

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