On the importance of fault modelling for seismic risk estimates

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in collaboration with
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The ESC-FAULT2SHA Central Apennines WG

https://fault2sha.net/

The virtual talk in a few words

Objective: Improve seismic risk estimates and local population awareness in the presence of active faults

Example In Central Italy ~ 400000 people live at less than 5 km from a known, mapped, active fault, capable of generating Mw>6

Strategy

Compute annual probability of collapse based on known activity of faults using the fault database compiled within the ESC FAULT2SHA WG (publication submitted Faure Walker et al., 2020).

Results

PART 1: Modelled EQ rates based on multi-fault ruptures are in reasonable agreement with catalogue and paleoseismic EQ rates. SHERIFS Model requires : double-GR frequency-magnitude distributions (FMD) , 20% reduction in geological slip rates and up to 6 (~10km long) sections rupturing together.

PART 2: Seismic risk profiles across the Central Apennines chain are radically different between Fault-based and area-based PSHA.

Conclusions

Considering activity of faults in seismic risk estimates better reflects the acquired geological knowledge and can radically change the perception of risk for the local population.

PART1
Modelling earthquake rates on faults

Methodology used : SHERIFS V1.2*

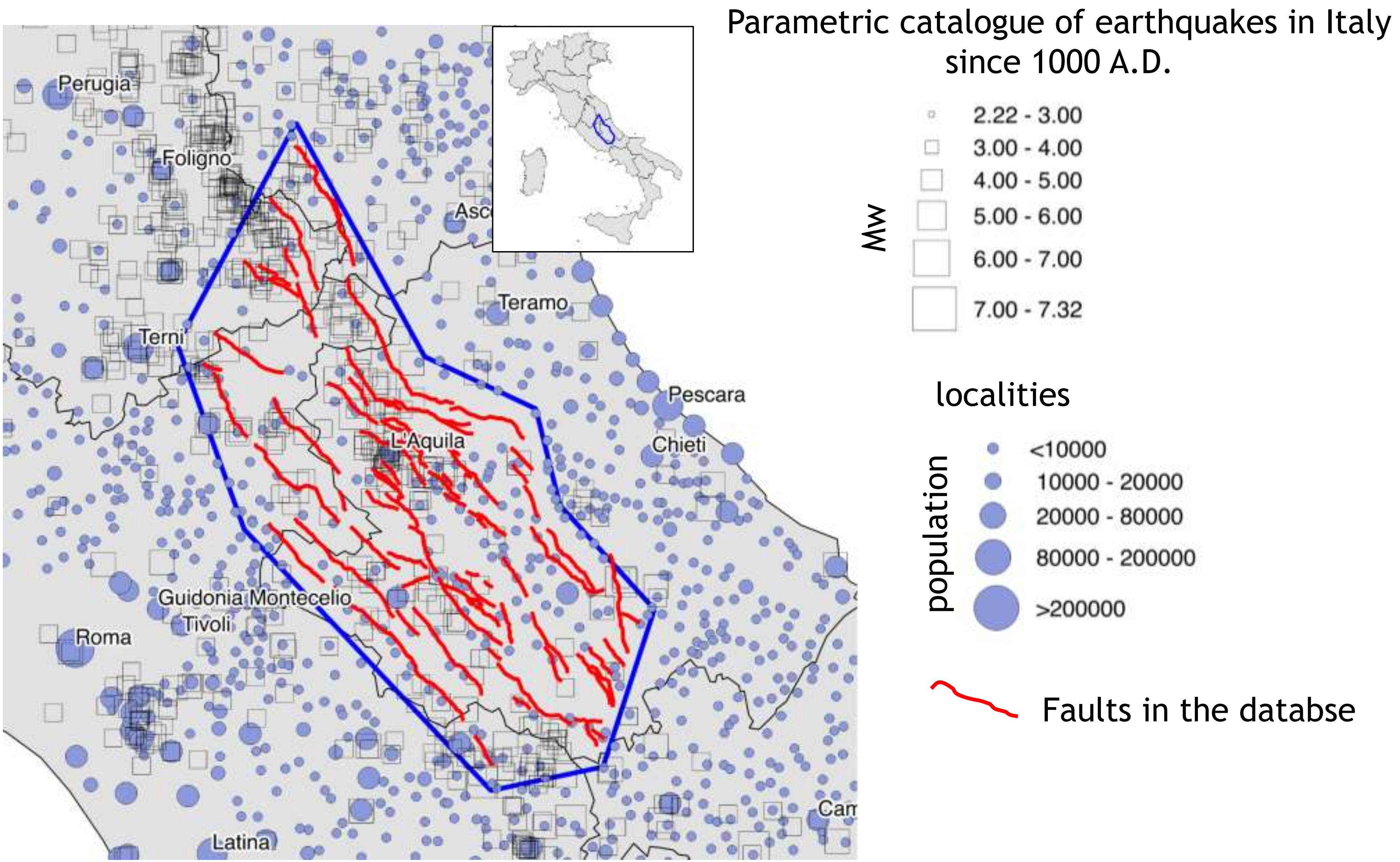
Inputs

- ❑ Geological Slip-rates and fault-trace geometries from the FAULT2SHA Central Apennines DB
- ❑ A list of Fault-to-Fault ruptures
- ❑ A shape for FMD of earthquakes (EQ)
- ❑ A background zone for computing observed EQ rates
- ❑ As many paleoearthquake studies as possible

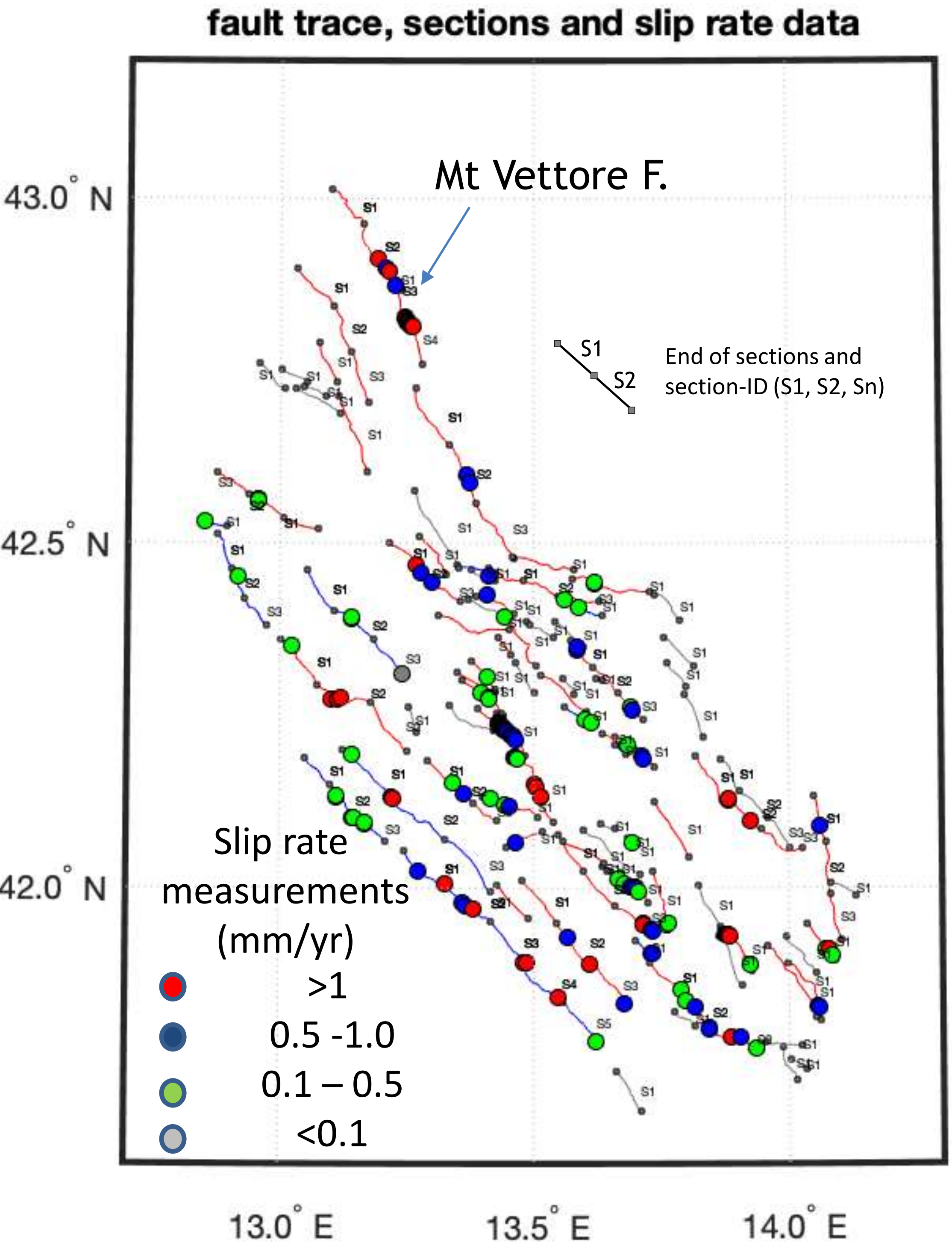
*Many thanks to Thomas Chartier for providing the updated version of SHERIFS: Open-Source Code for Computing Earthquake Rates in Fault Systems and Constructing Hazard Models SRL,- Chartier et al. 2019 doi. 10.1785/0220180332 SRL

Area of Study: The Central Apennines

A region characterized by a network of NW-SE normal faults accommodating ~3 mm/yr NE-W extension



1-Raw database: trace of faults with slip rate measurements



All Class I-III Faults with slip rate measurement provided in the DB are considered

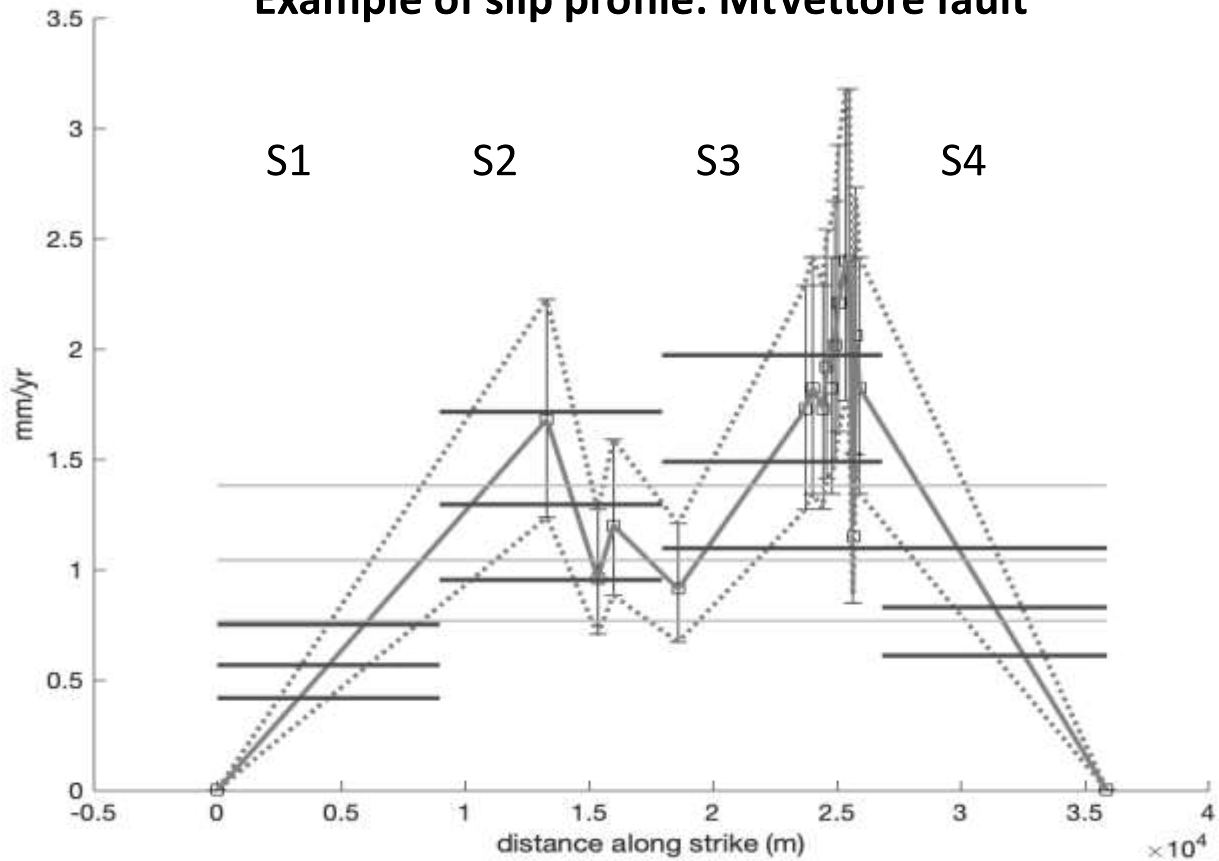
Classes of Fault Activity		#
RED Class I	Dated displacement during Late Pleistocene - Holocene (palaeoseismic trench, modern earthquake, cosmogenic dating)	44
BLUE Class II	Evidence of Late-Pleistocene displacement, but without in situ dated Late-Pleistocene Holocene displacement	12
GRAY Class III	Geologic (displaced Middle Pleistocene deposits) or geomorphic evidence of potential fault activity, but this has not been confirmed as Late-Pleistocene	32

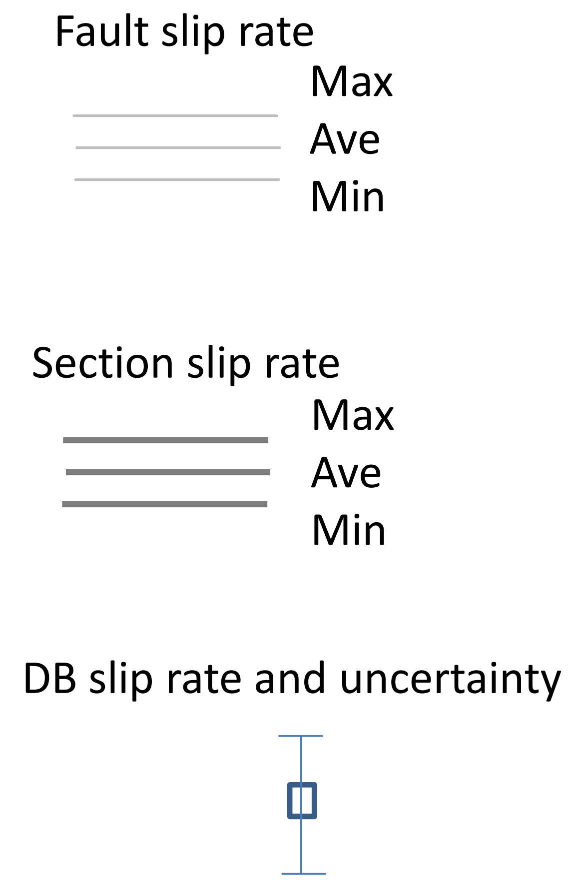
2-Fault modelling: defining sections and building slip rates profiles

Hypothesis:

- Geol. Slip rates go to zero at Fault ends
- Considered section-dependent slip rate estimates
- NB: Geol. Slip rates reduced by 20% to account for post-seismic moment release/aseismic crrep
- Seismogenic depth, Dip of faults

Example of slip profile: MtVettore fault





Sx = ~10 km long sections

3-Multifault ruptures: combining sections to create earthquake ruptures

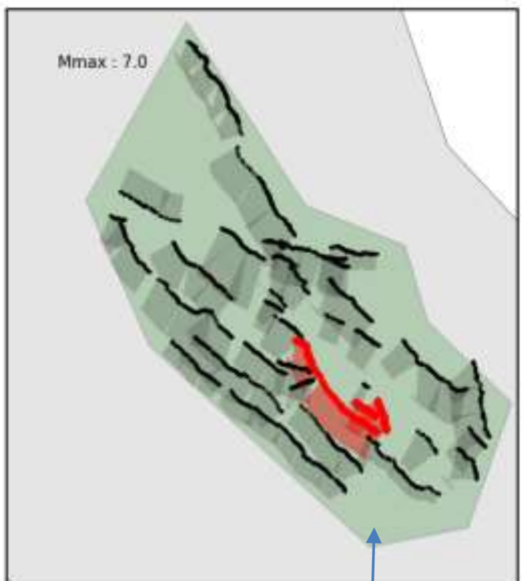
Hypothesis:

All rupture scenarios involving sections less than 5 km apart can rupture together

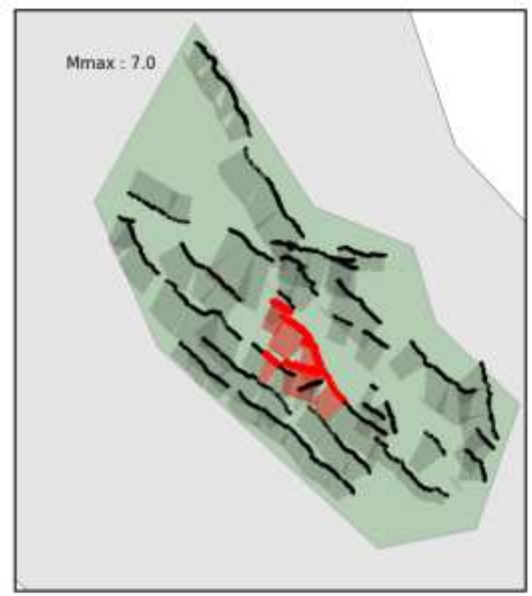
Maximum number of sections considered = 6

Exemple of multi-fault ruptures considered

Fucino_1 Fucino_2 Fucino_3 OvindoliPezza_1 Parasano_1 SanSebastianc



CampoFelice_1 Fucino_1 Magnola_1 MtVelino_2 Ocre_1 OvindoliPezza_

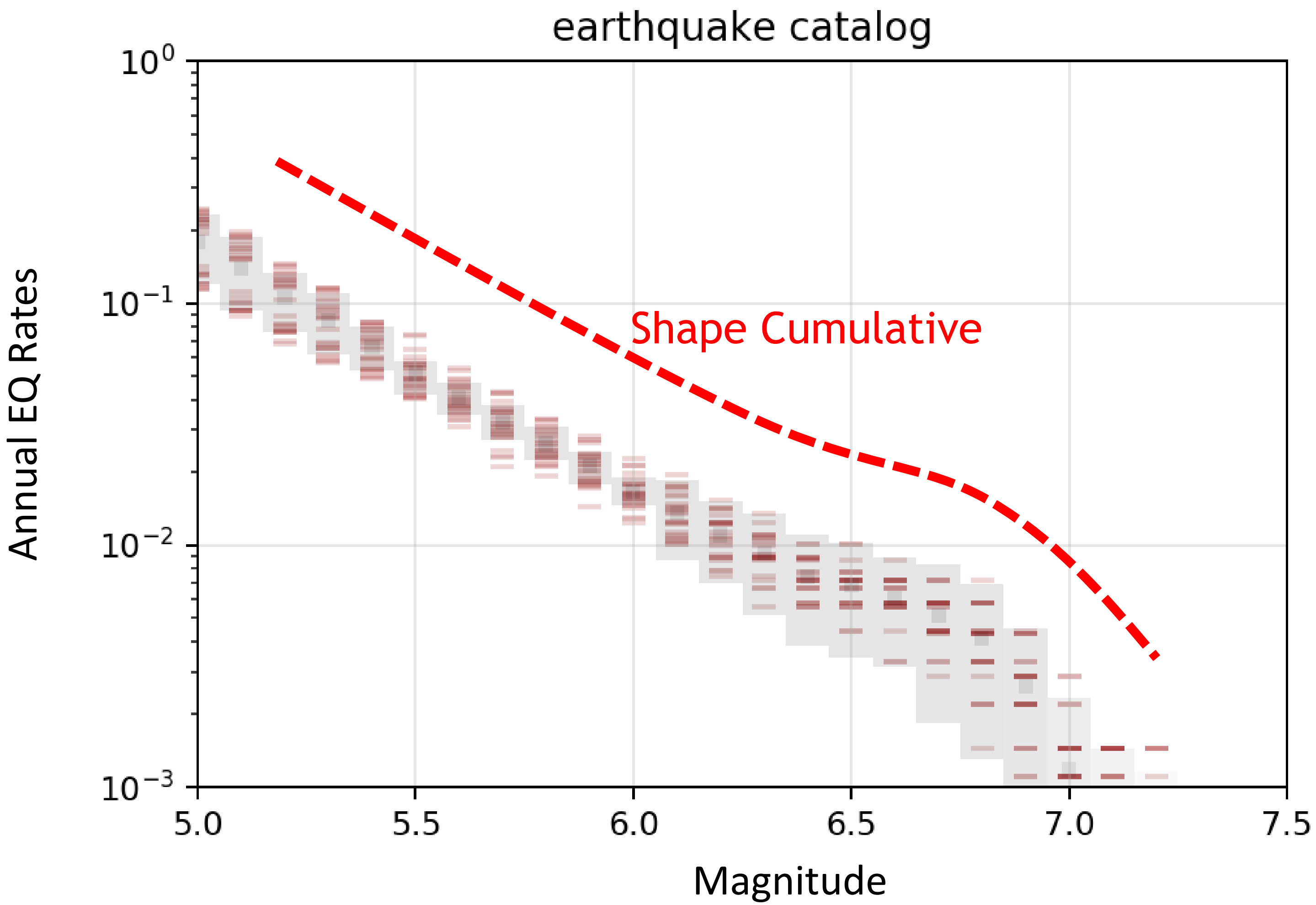


Background zone considered for computing EQ rates from the catalogue

4- Shape of the Frequency-Magnitude Distribution (FMD)

Hypothesis:

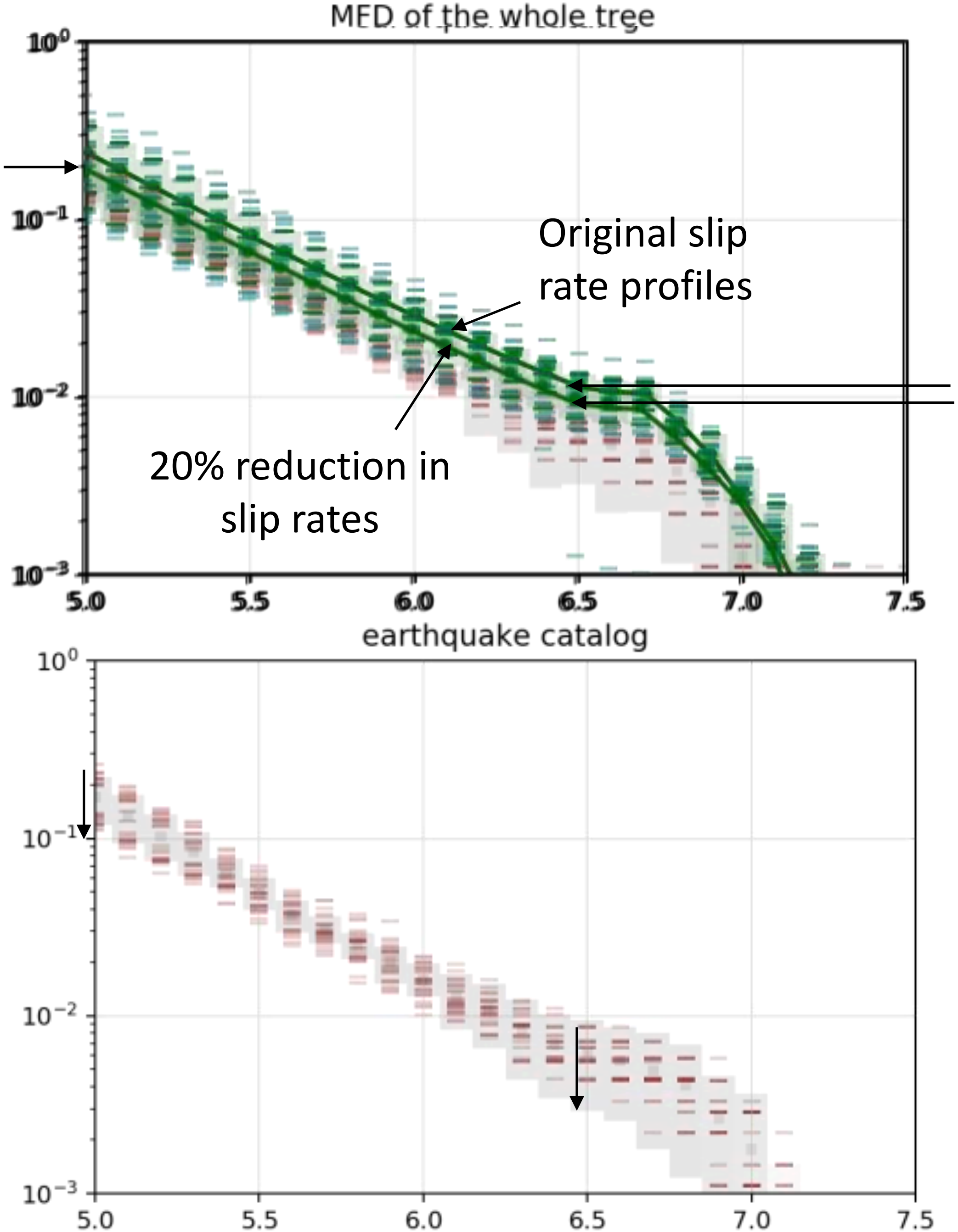
Parametrize an FMD shape closely resembling that observed in the catalogue



SHERIFS Modelling results: comparison with catalogue EQ rates

M>=5
Rec = 5/6 years

M>=6.5
Rec = 66 years
Rec = 100 years



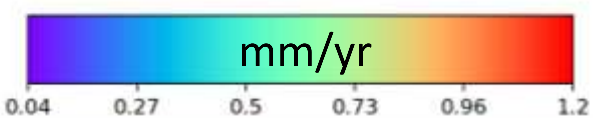
M>=5
Rec = 10-5 years

M>=6.5
Rec =250-100years

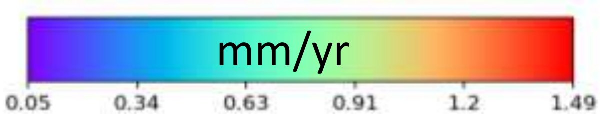
SHERIFS outputs: seismic vs aseismic slip rate

Input slip rates

Original slip rate profiles
Reduced by 20%

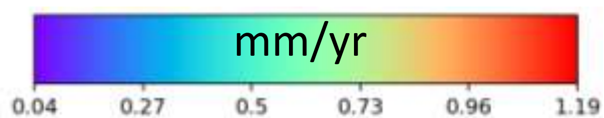


Original slip rate profiles

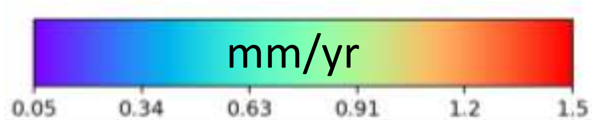


Output slip rates ==>EQ rates

« seismic slip rate »

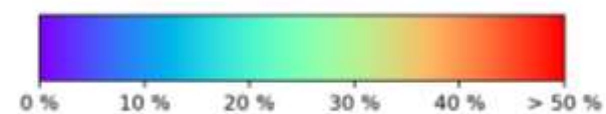


« seismic slip rate »

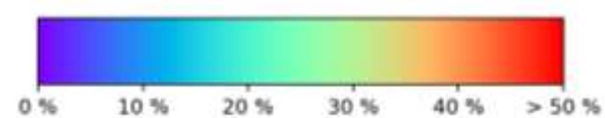


Output slip rates ==>aseismic

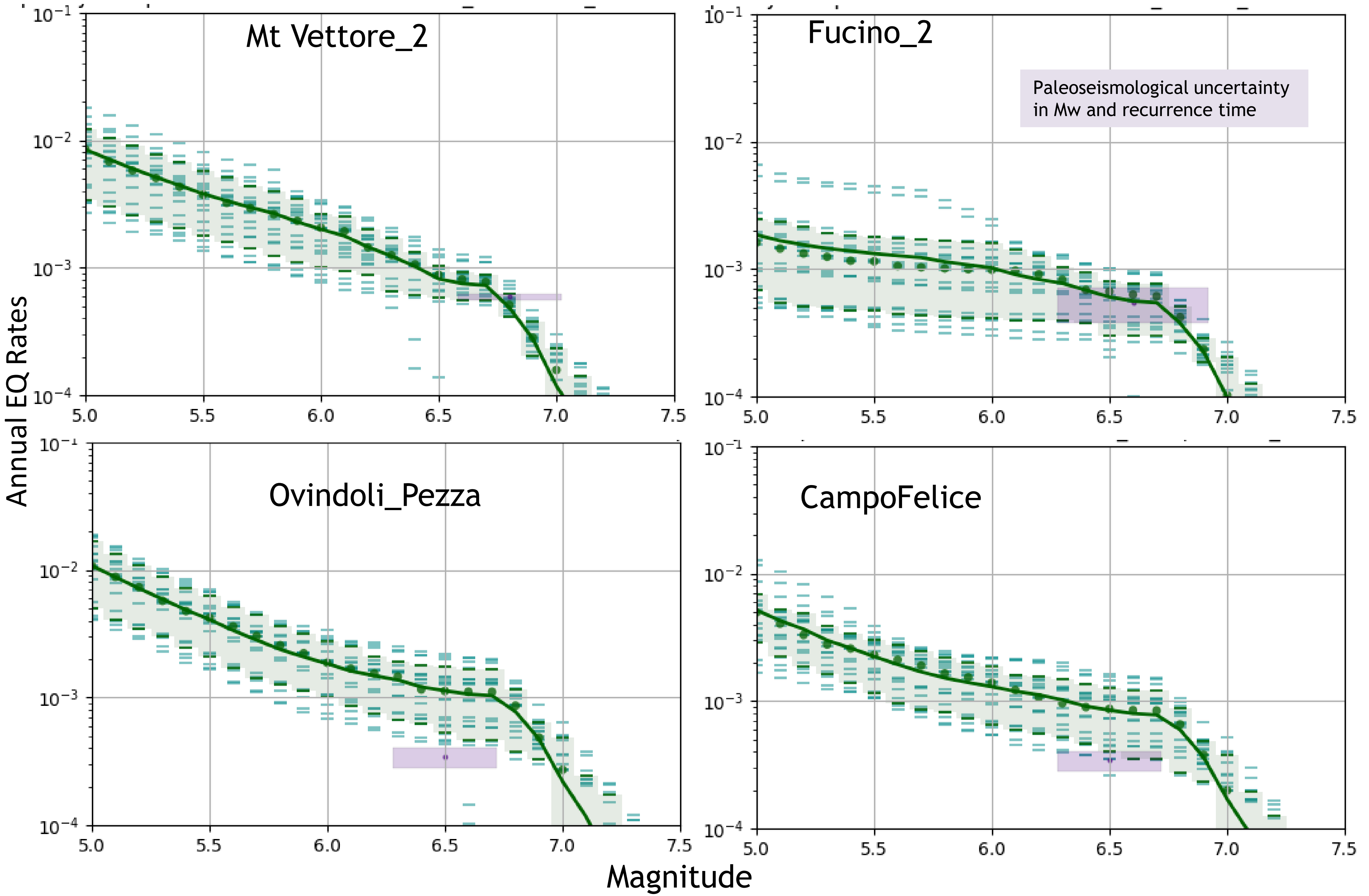
« % aseismic slip rate »



« % aseismic slip rate »



SHERIFS Modelling results: comparison with paleo EQ rates (Galli et al, 2008)



PART1: SHERIFS conclusions

Reasonably good agreement between EQ rates deduced from the catalogue and from paleo-seismic studies with EQ rates modelled with SHERIFS assuming:

- multi-fault ruptures (up to 6 10 km-long-segments),
- double-GR FMD
- a 20% reduction in the geological slip rates of the Central Apennines FAULT2SHA database

PART 2 Modelling probability of collapse

Ingredients

1. Hazard Curves
   - SHERIFS FMDs + 4 recent GMPE applicable to Italy
2. Risk
   - published fragility curves

Calculation Steps*

- Fault-based Hazard curves
- Area based hazard curves using same FMD from SHERIFS
- Annual Probability of collapse

*Using the Openquake Engine

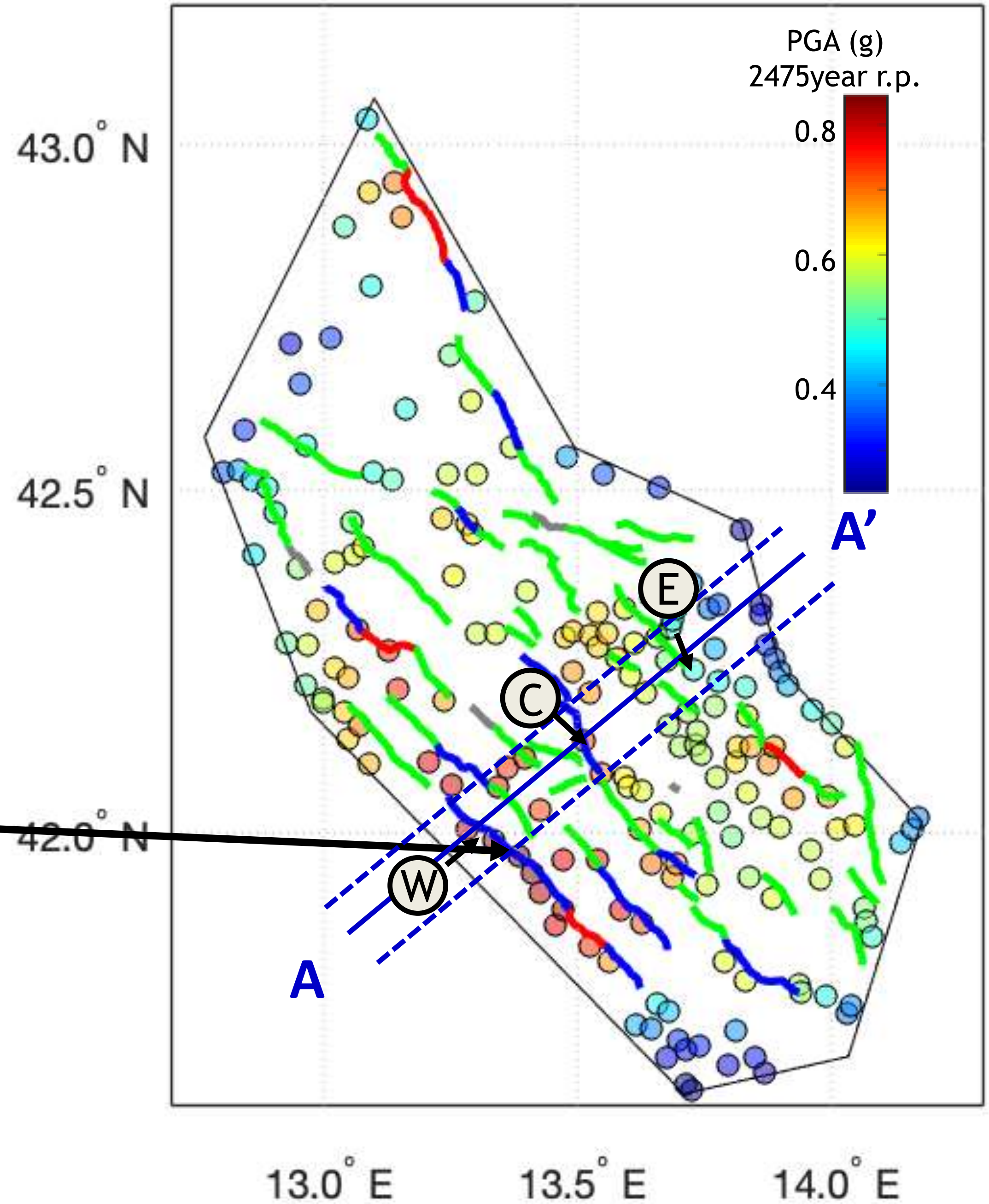
1 - Fault Hazard at the localities

Sections Slip rate (mm/yr)

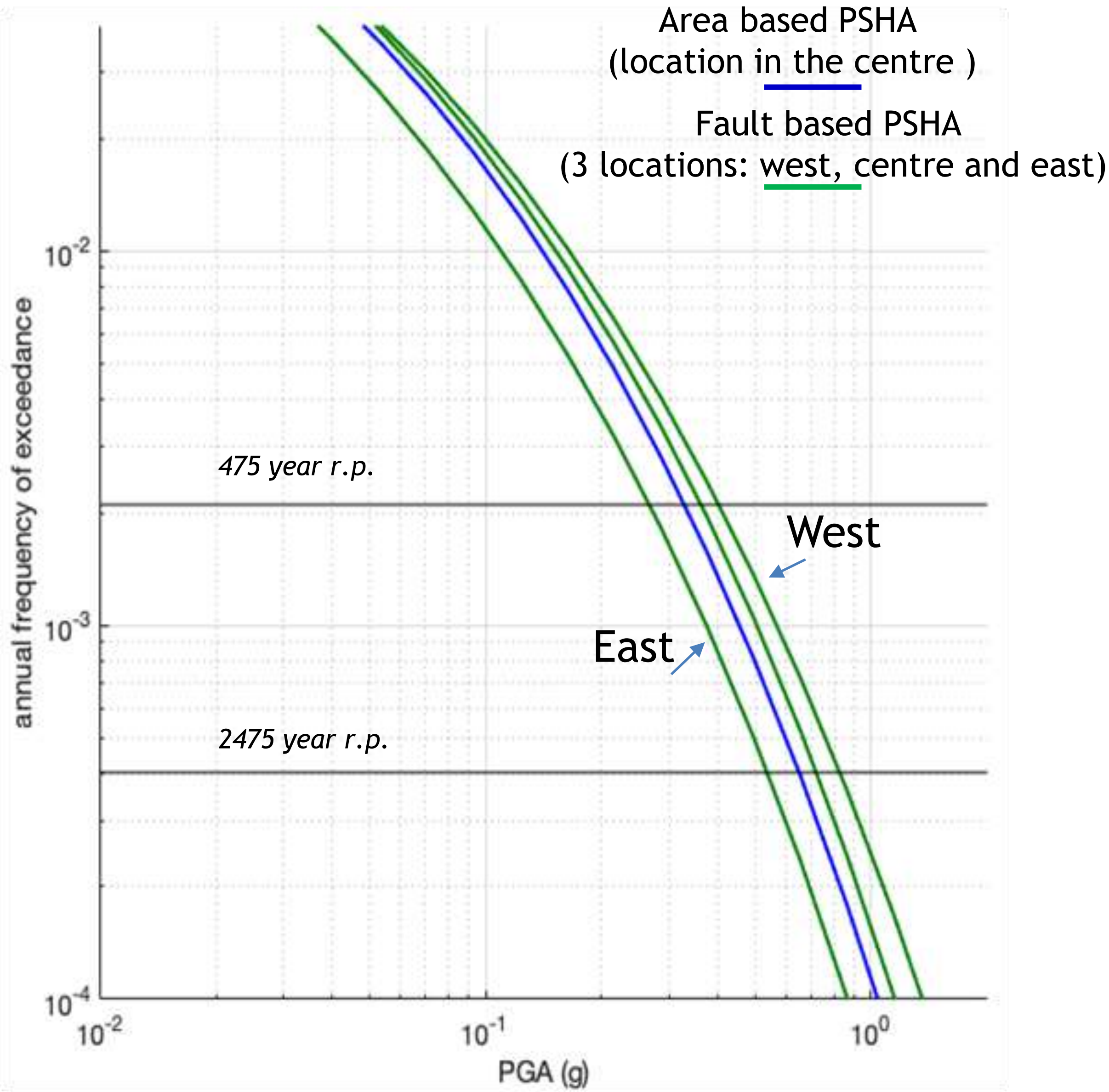
- >1
- 0.5 -1.0
- 0.1 – 0.5
- <0.1

Liri fault slip rates currently under revision!!

➔ Need for paleoseismological Investigations



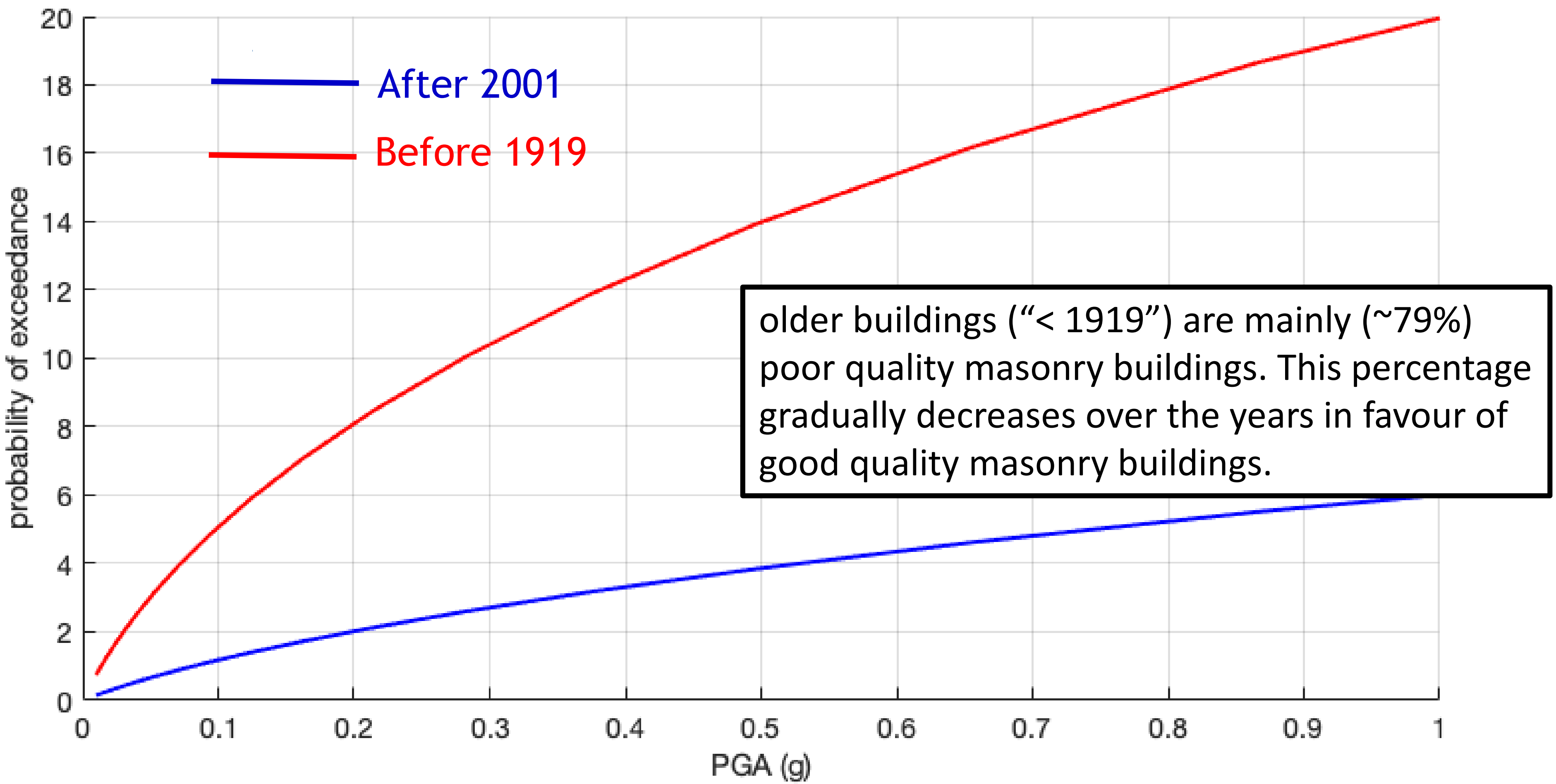
1-Hazard Curves: Fault vs Area (section A- A')



Seismic Hazard higher in the west where on average fault activity is higher compared to the eastern part of the study area

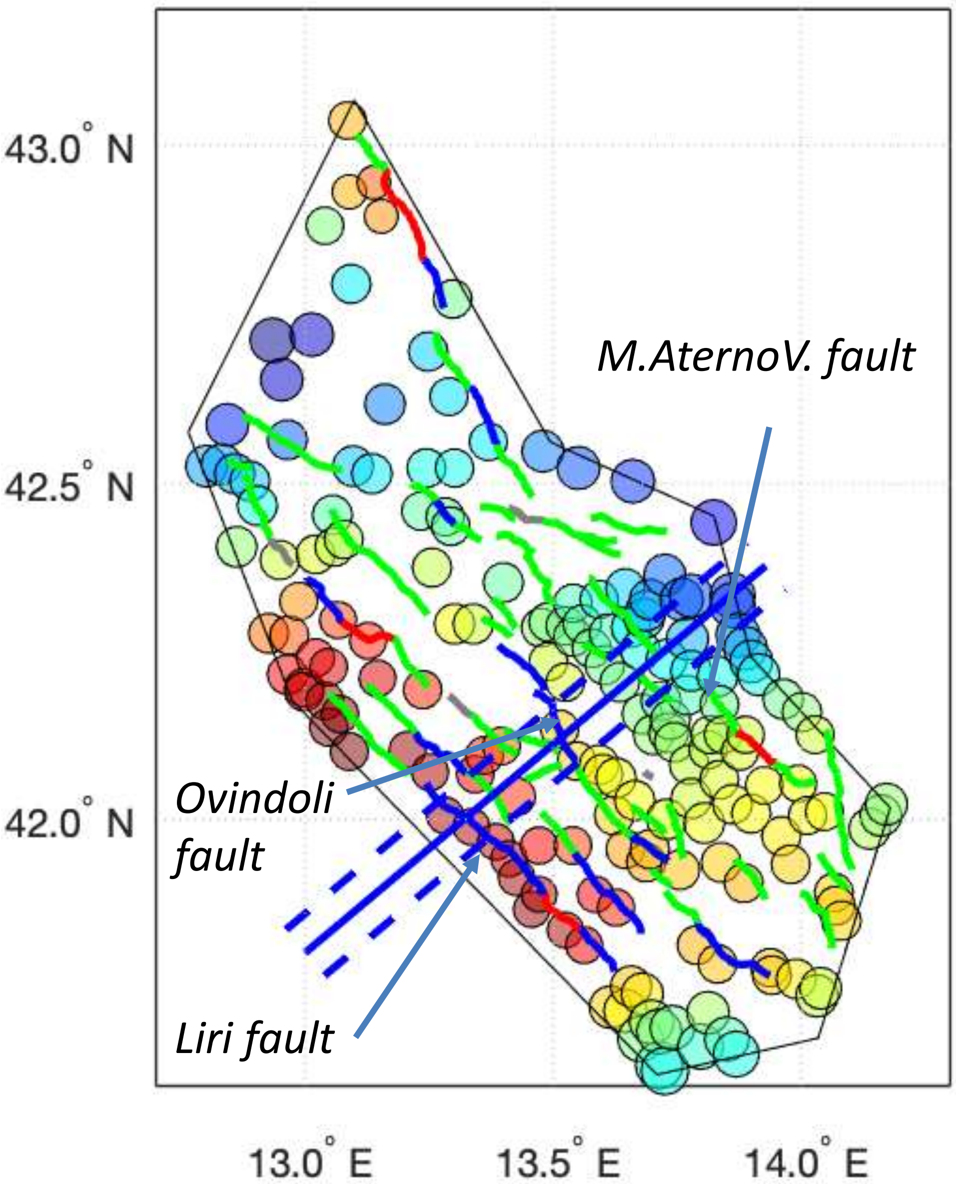
2- Published Fragility curves

Fragility curves (Del Gaudio et al., 2019) obtained as weighted averages of 14 building specific sets of curves with the percentages of occurrence of each class used as weights for the considered time intervals

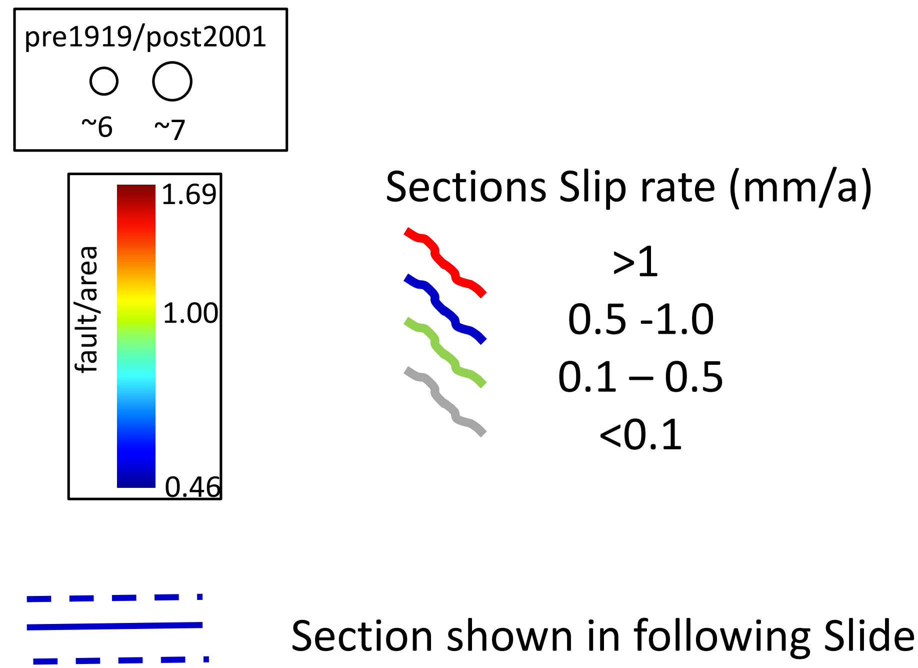


Del Gaudio, C., De Martino, G., Di Ludovico, M. *et al*. Empirical fragility curves for masonry buildings after the 2009 L’Aquila, Italy, earthquake. *Bull Earthquake Eng* **17**, 6301-6330 (2019). https://doi.org/10.1007/s10518-019-00683-4

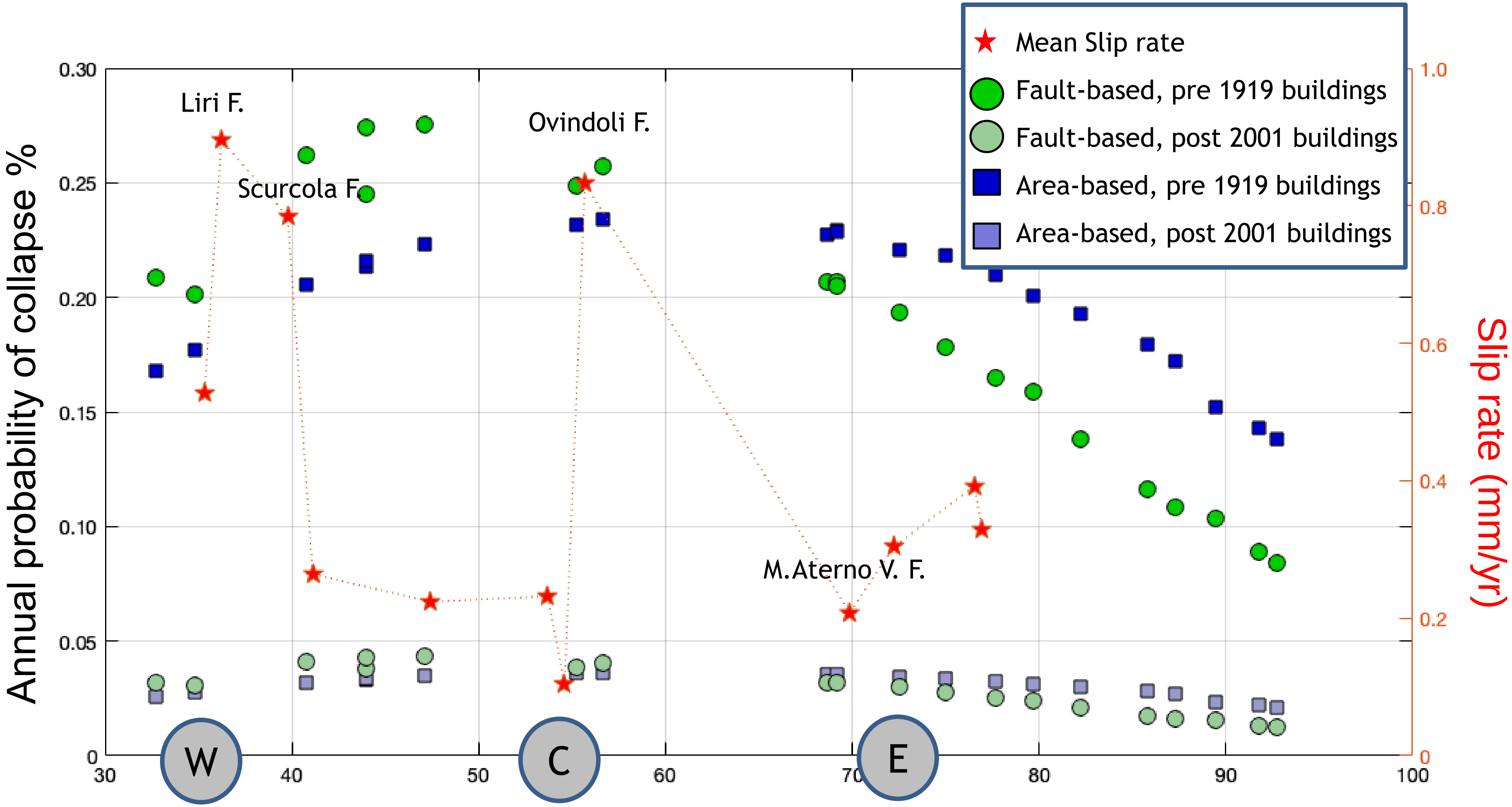
2 - Risk results – map



Area (A)/Fault (F) risk ratios
AND pre1919/post2001 buildings seismic risk



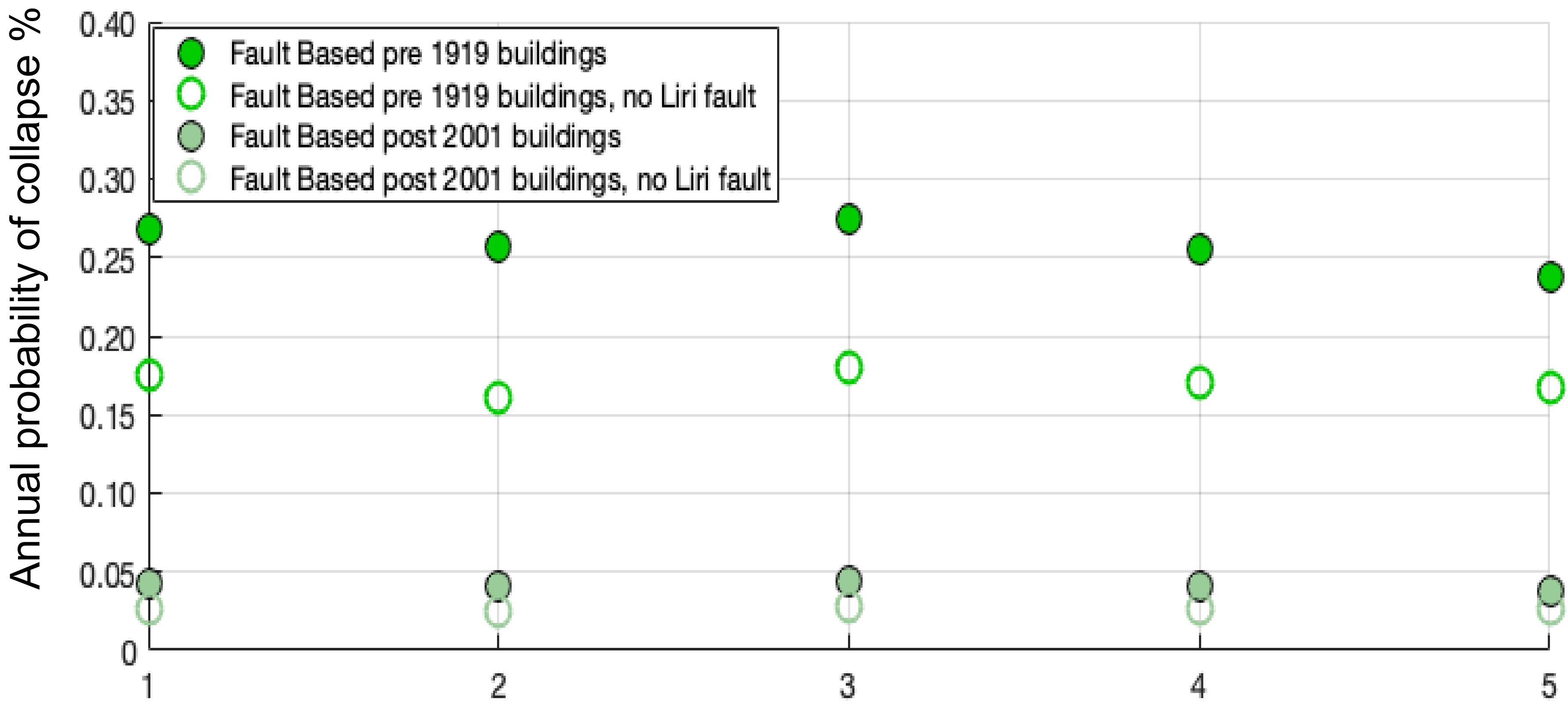
2- Risk results – section



W, C and E are locations where seismic hazard curves are shown on Slide 15

2- Risk results – Sensitivity Test to Class II-type faults

Example at 5 localities along the southern Liri F. trace: Active (Liri F in the model) vs Inactive (Liri F. not modelled)



➔ Crucial to confirm/infirm slip rates along Class II and III faults

PART 2: RISK **preliminary** conclusions

- Seismic risk of post 2001 building is considerably reduced compared to pre 1919 building.
- Seismic risk profiles across the Central Apennines are remarkably affected by the use of a Fault-based approach.
- The western part of the study section is more at risk than the eastern part, where active faults are characterised by considerably lower slip rates.

Risk results presented here are preliminary, in particular along Class II and III faults, affected by great uncertainties (e.g. the Liri Fault where Geological investigations are still ongoing)

ONGOING WORK

Continue the constructive feedback between Data providers and PSHA modelers within the Central Apennines FAULT2SHA ESC WG

1. How to best represent uncertainties in geological interpretations in faultDB and properly propagate them in Fault-PSHA (e.g. Liri Fault)?
2. Use finite displacement profiles to define tips properly, to show where ruptures have and have not occurred over several million years
3. Add background seismicity ➔ degree of completeness of the fault DB (i.e. Mt Vettore Fault region, the fault network is not completely characterized + Not all strands/sections/traces have been mapped)
4. Looping back with geologists/geodesists to refine the aseismic component of the fault model instead of a 20% reduction
5. ….Time-dependency, …Physics-based approaches..