Fault displacement hazard: Taming the beast for engineering applications

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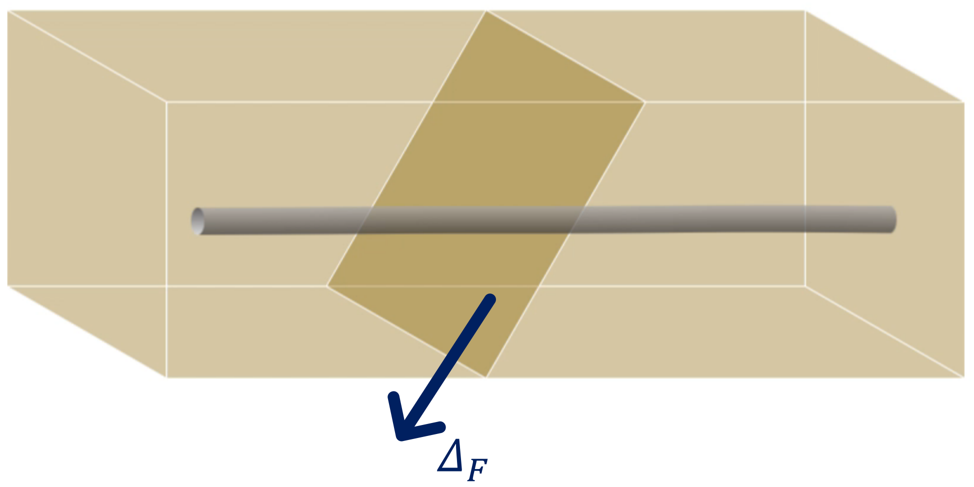
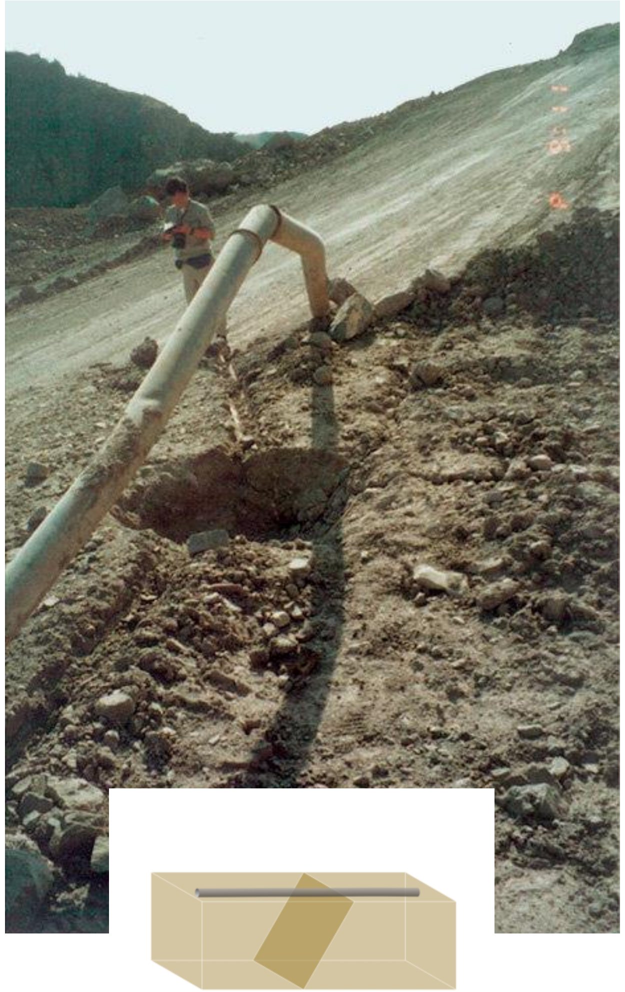
The 49th Risk, Hazard & Uncertainty Workshop

Tectonic fault displacement



Failure of lifelines due to tectonic faulting

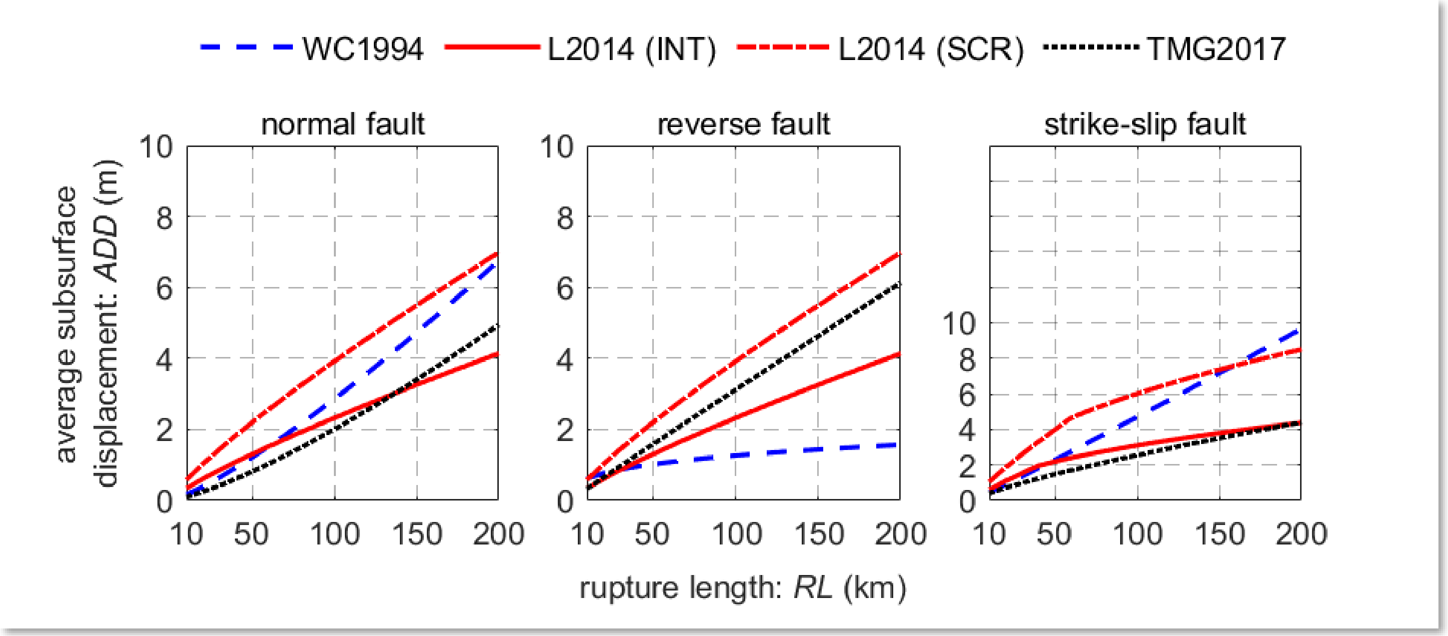


How to calculate the fault displacement?

- Until now …
  - Empirical fault scaling relations
  - Full seismological study € € € €
- From now on …
  - & Code approach: **Annex E (informative) of prEN 1998-4:2022**

Empirical fault scaling relations

- Advantages
  - Easy-to-use
  - Minimum data requirement
  - Based on fault dimensions (length, width, depth, rupture zone, earthquake magnitude, etc.)



- Disadvantages
  - Unknown or insufficient defined level of safety
  - Actual distribution of fault events not considered
  - No guidelines available for choosing a set or relations

Fault displacement

Full seismological study

- Probabilistic Fault Displacement Hazard Analysis (PFDHA) by Youngs et al. (2003) or Petersen et al. (2011).

the beast!

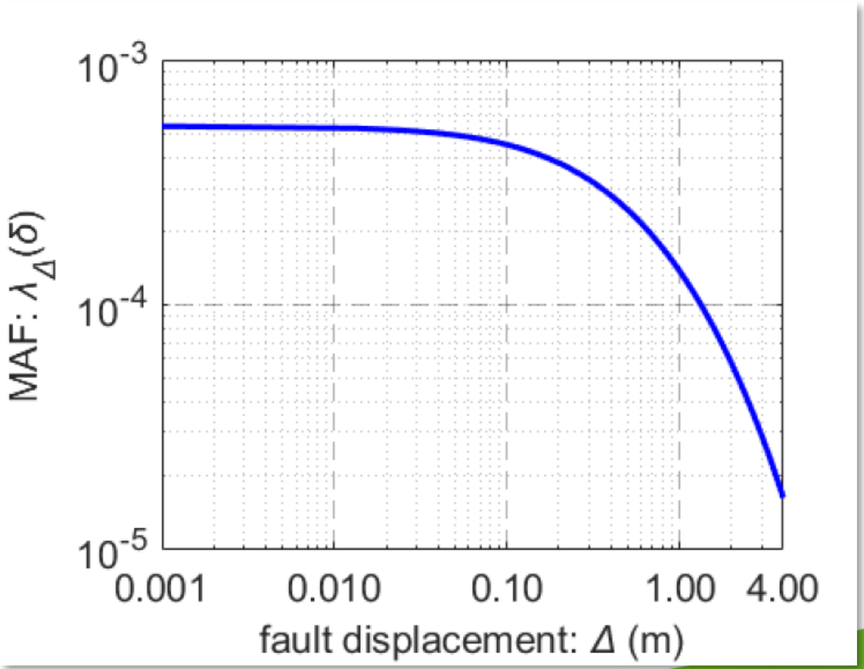
- A simplified approach of PFDHA for lifeline-fault crossings.
- Mean annual frequency:

$$\lambda_{\Delta_F}(\delta_F) = v_F \sum_i P\left(\Delta_F > \delta_F \middle| m_i\right) P_M(m_i)$$

$$P\left(\Delta_F > \delta_F \middle| m_i\right) = \sum_j \sum_t \sum_k P\left(\Delta_F > \delta_F | m_i, RL_j, ADS_t, Pos_{j,k}\right) P\left(RL_j, ADS_t \middle| m_i\right) P\left(Pos_{j,k}\right)$$

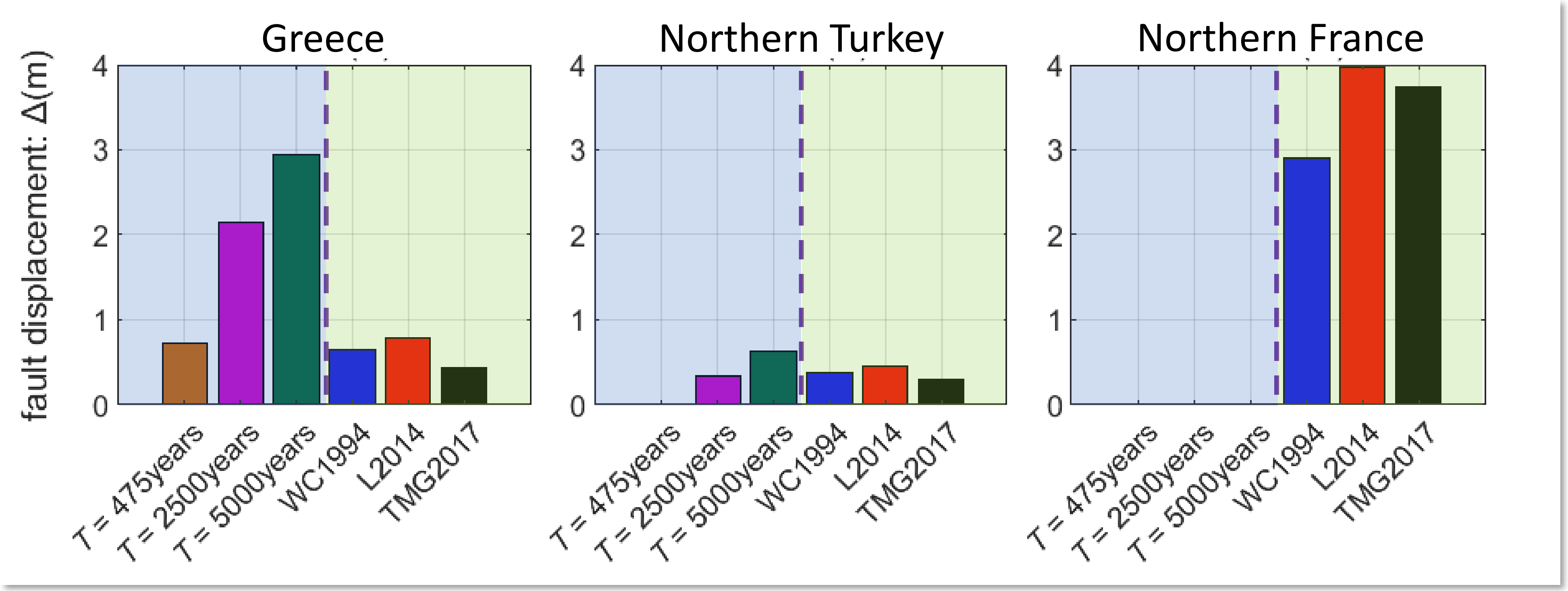
Full seismological study

- Advantages
  - Compatibility with Performance-based Earthquake Engineering
  - Actual distribution of fault events
  - Calculation of fault displacement for given return period
- Disadvantages
  - A lot of specialized seismological data
  - Advanced calculations
  - Not compatible "as is" with code provisions



Fault displacement

Empirical fault scaling relations versus a full seismological study



Greece: medium length 40.14km + high seismicity

Northern Turkey: small length 20.66km + medium seismicity

Northern France: very high length 215.71km + very low seismicity

Our goal

Target

Tame the beast, aka PFDHA

Introduce a simplification of PFDHA in the code

Calculate fault displacement for given return period

- Hazard-consistent
- Use of data available to engineers
- Eurocode-compatible

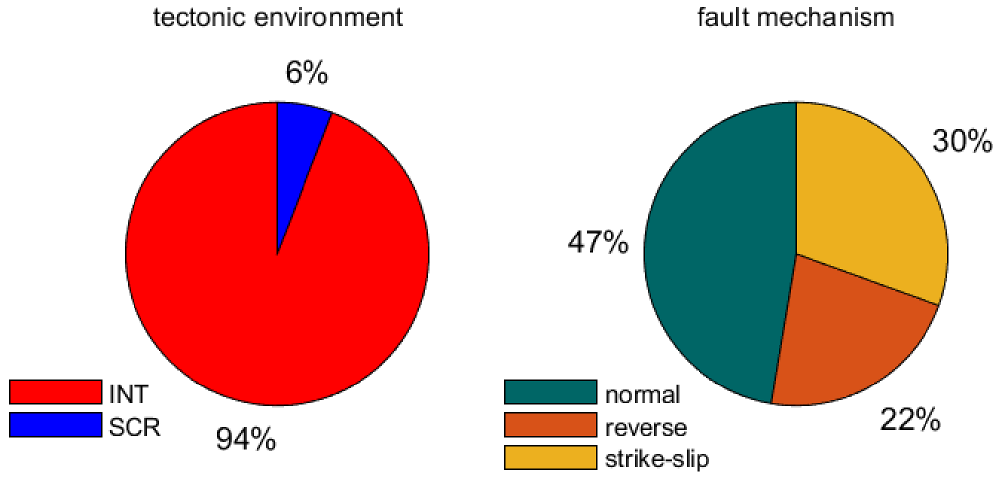
Approach background

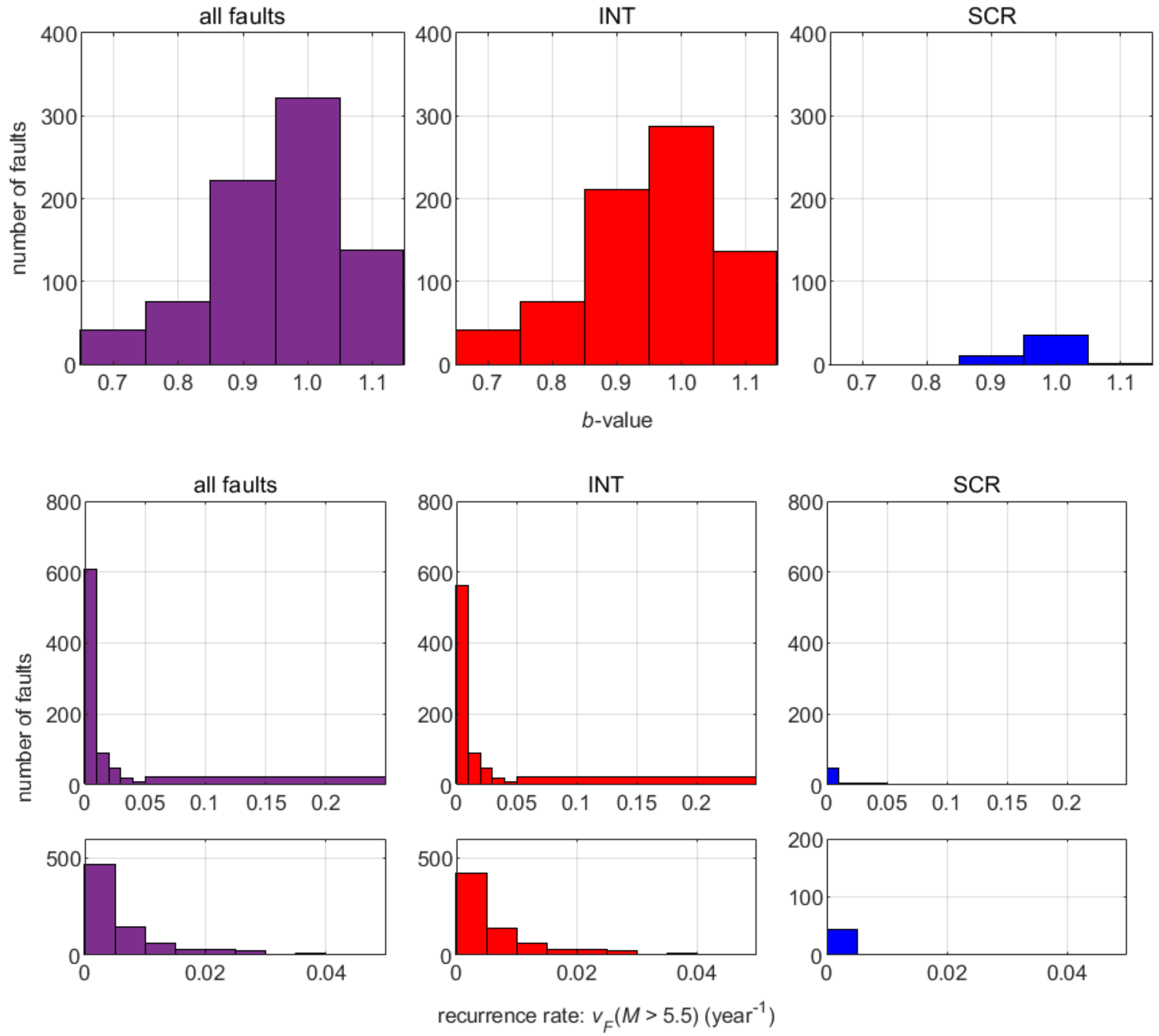
Outline

- PFDHAs
- Handling of uncertainties via logic trees
- Parameters of faults in Europe from the 2020 European Fault-Source Model (EFSM20)

Approach background

Statistical processing of fault data





Approach implementation

- 1st step: Fault mechanism and length & fault crossing site
- 2nd step: Recurrence rate v_F
- 3rd step: Return period (T_R) for given fault displacement (Δ_F) or vice-versa:

$$T_R(\Delta_F) = \frac{1}{C_F v_F f_L(\Delta_F, L_F, X_L)}$$

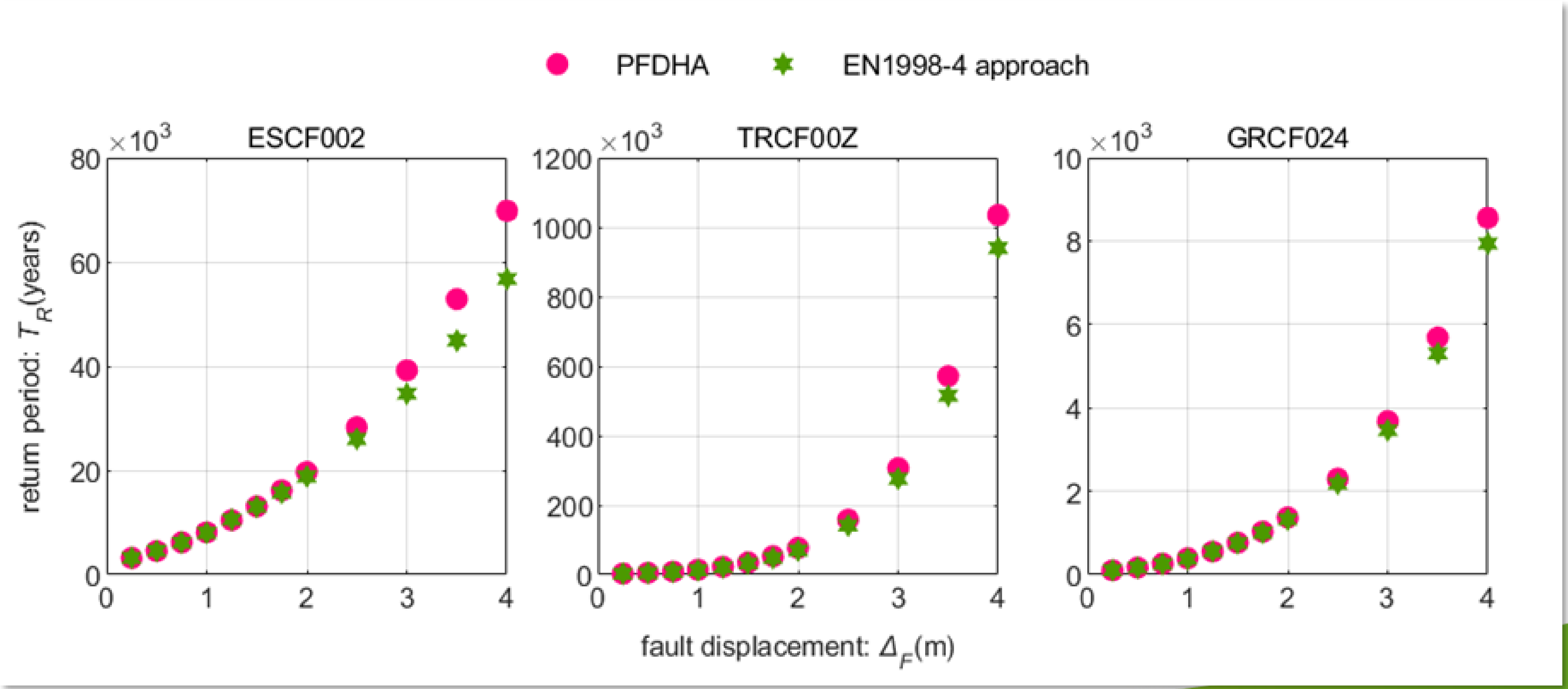
where:

C_F = confidence factor

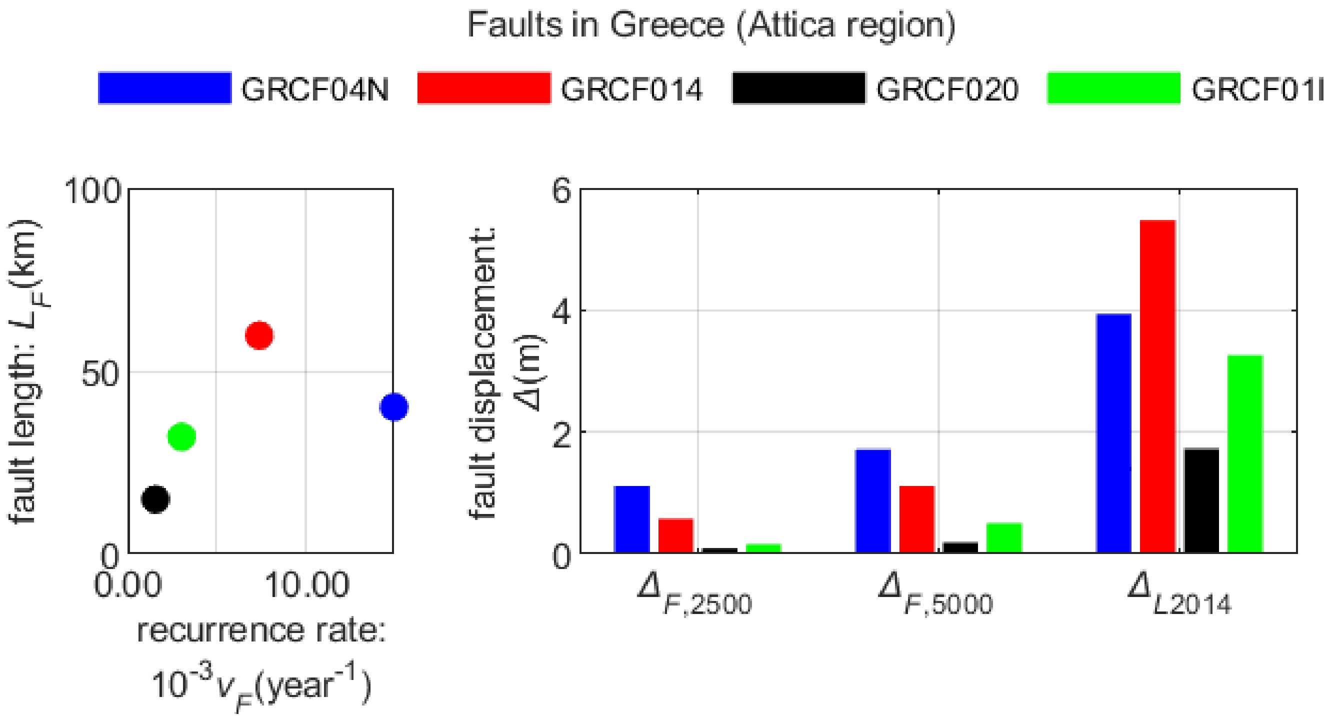
$f_L(\Delta_F, L_F, X_L)$ = function depending on the fault mechanism, fault length, and crossing point; estimated using tables

Evaluation of results

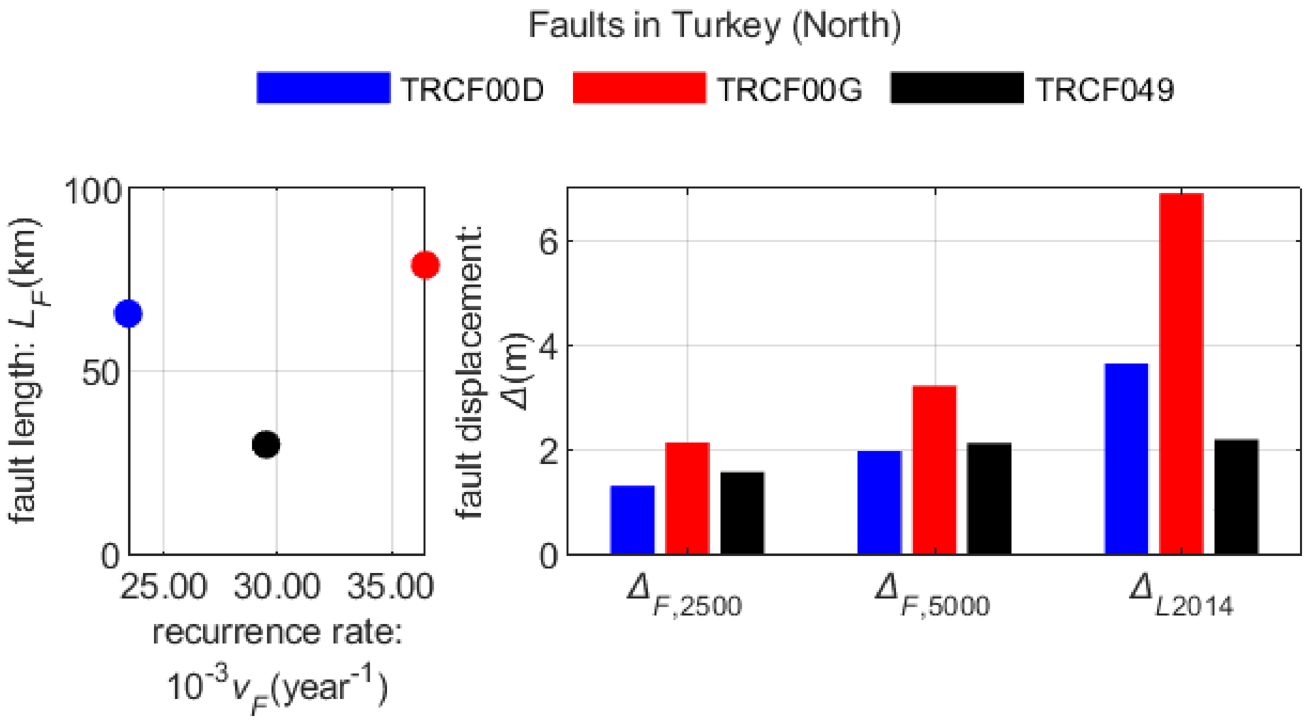
Fault	Country	Tectonic env.	Mechanism	Length (km)	Recurrence rate (years^{-1})
ESCF002	Spain	Interplate	Reverse	114.06	0.00778
TRCF00Z	Turkey	Interplate	Strike-slip	25.28	0.00298
GRCF024	Greece	Interplate	Normal	38.42	0.08486



Short and medium length faults in Central Greece with high recurrence rate



Short and medium length faults in Northern Turkey with very high recurrence rate



Engineering implementation

- A structure-independent approach → use for on-ground or buried (not deep-buried tunnels) lifelines

- A tool for:
  - Route selection of lifelines in seismic areas
  - Preliminary earthquake-resistant design
  - Assess the need for full seismological study

Thank you for your attention!

Acknowledgements

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