

Valorization of the recent probabilistic seismic hazard results

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Outline

- Backgrounds to probabilistic hazard analysis (PSHA)
- Use of seismic hazards in probabilistic risk analysis (PRA) and engineering qualification
- Seismic hazard results and their processing
- Results / Conclusions

Backgrounds to PSHA

- Probabilistic hazard analysis (PSHA) is the **method to calculate seismic hazard** in Finland.
- The outcome are a range of **hazard curves**. The range represents the uncertainties in the seismic model conceptualization.
- Reporting, summarizing and **utilizing the hazard curves in different ways** is debated in the literature (e.g. as mean, median, 84th percentile etc.).
- Sometimes a **single value/threshold** of the hazard is needed, e.g. for deterministic engineering qualification or regulatory purposes.

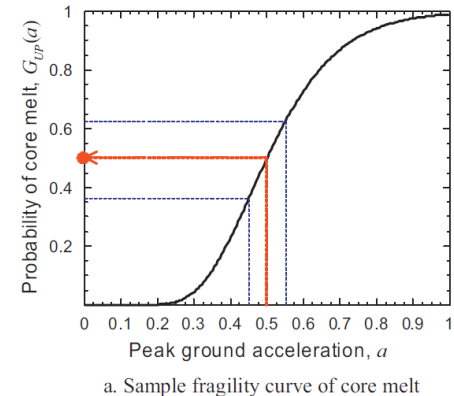
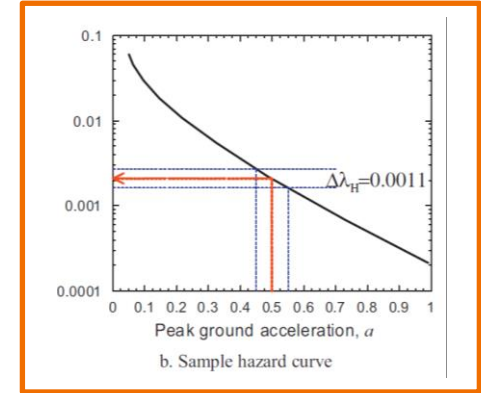
Seismic hazards in PRA and engineering

- **Mean hazard** is used in PRA. The hazard is integrated with the fragility (see figures) to estimate the frequency of unacceptable performance.

$$\lambda_{UP} = \int G_{UP}(a) \left| \frac{d\lambda_H(a)}{da} \right| da$$

λ_{UP} is the annual frequency of unacceptable performance

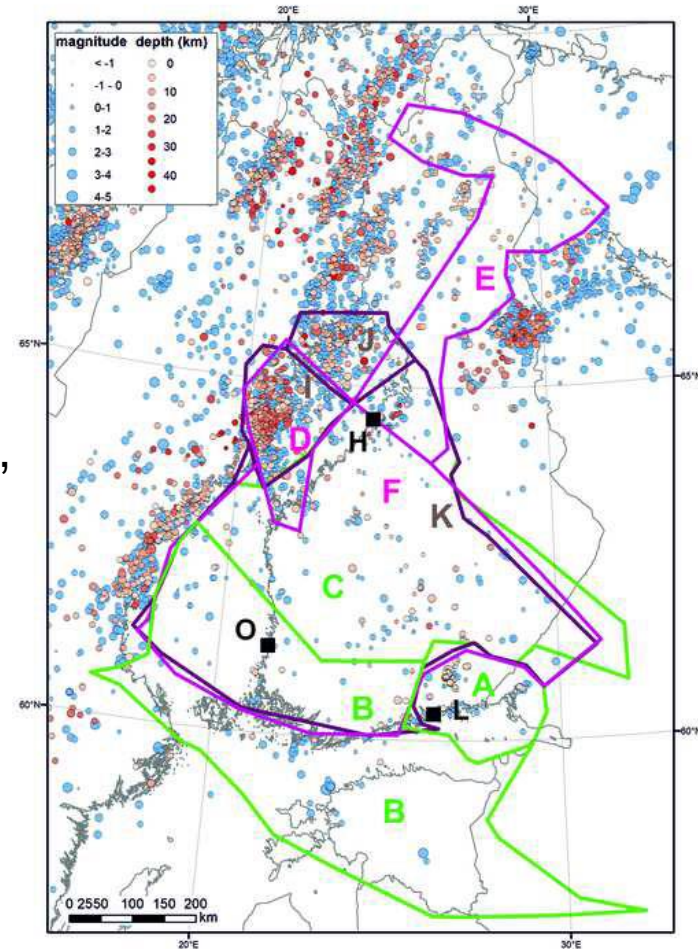
- **Median hazard** with annual frequency of exceedance (AFE) of 10^{-5} is the design basis earthquake (DBE). Design extension earthquake (DEC C) have 10^{-7} AFE.
- The use of median hazard for DBE is a minority position among regulators.



Mean hazard curve and mean core-melt fragility curve.
(Huang *et al.* 2011 DOI: 10.1016/j.nucengdes.2011.06.051)

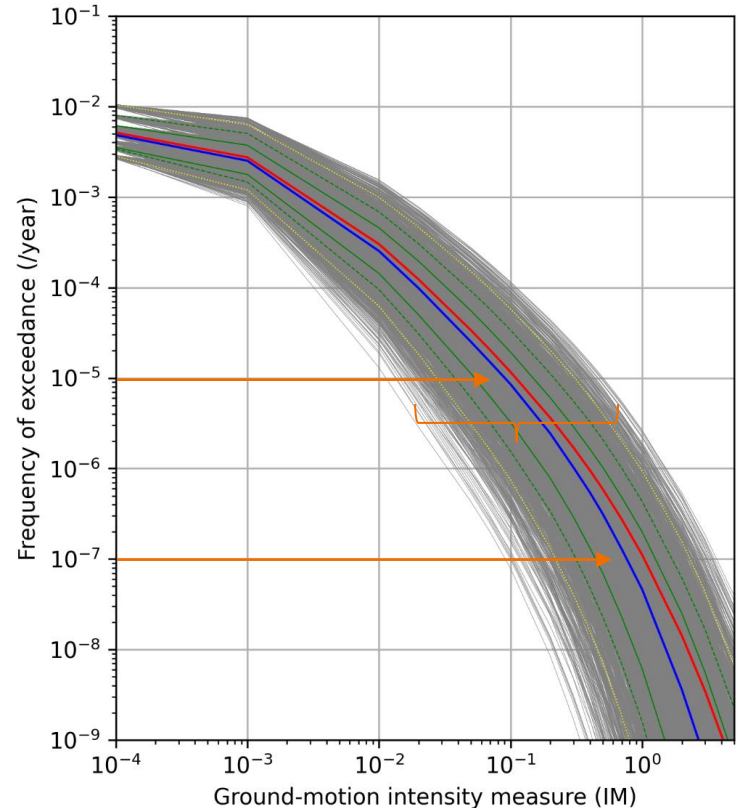
Available PSHA results (1)

- Project contracted by STUK 2019-2020. Outcomes:
 - Detailed SENSEI report of STUK;
 - Main results published e.g.: Fülöp, L., Mäntyniemi, P., Malm, M., Toro, G., Crespo, M.J., Schmitt, T., Burck, S., Välikangas, P., 2022. *Probabilistic seismic hazard analysis in low-seismicity regions: an investigation of sensitivity with a focus on Finland*. Nat Hazards. <https://doi.org/10.1007/s11069-022-05666-4>



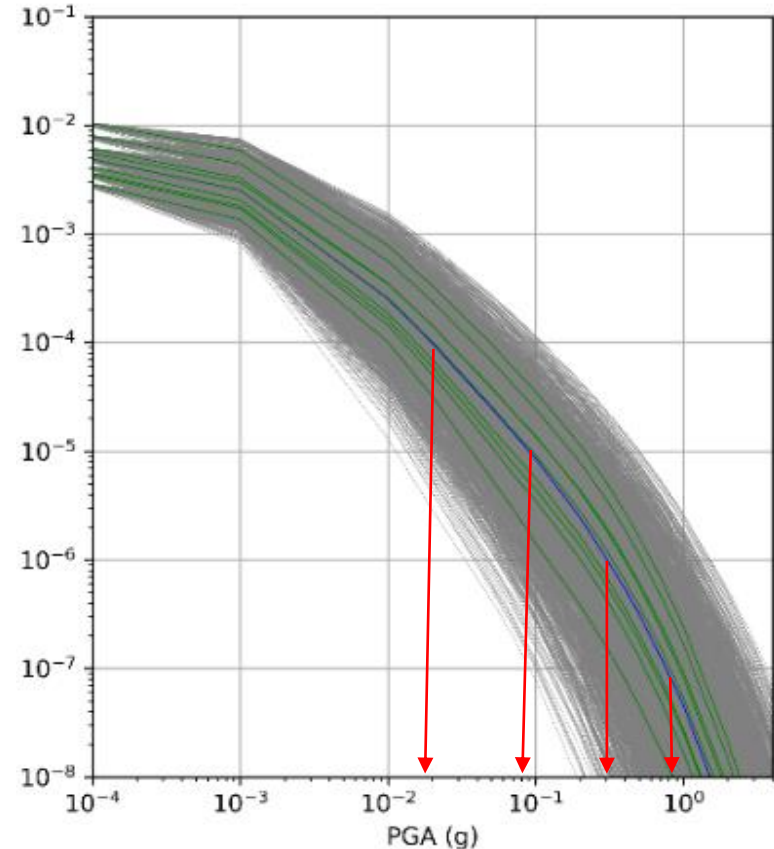
Available PSHA results (2)

- Example hazard curves for NPP site in Finland.
- Range of grey lines show the epistemic uncertainty. Green are different fractiles. Blue line is the **median hazard**; red is the **mean hazard**.
- At 10^{-5} - 10^{-7} AFE, the hazard range is broad and the **mean to median difference** increases (*Note: horizontal axis in log-scale*).



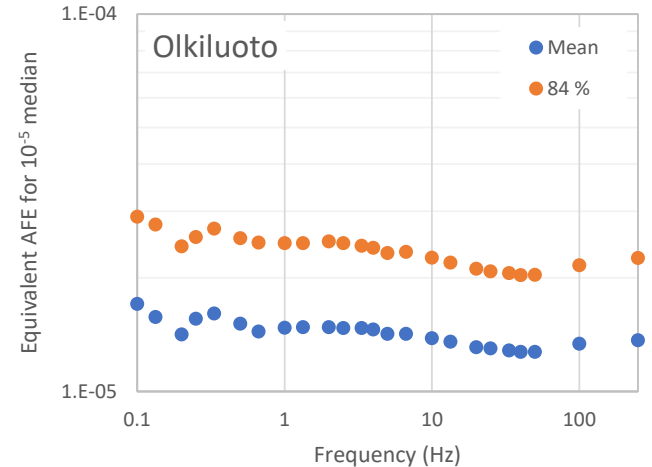
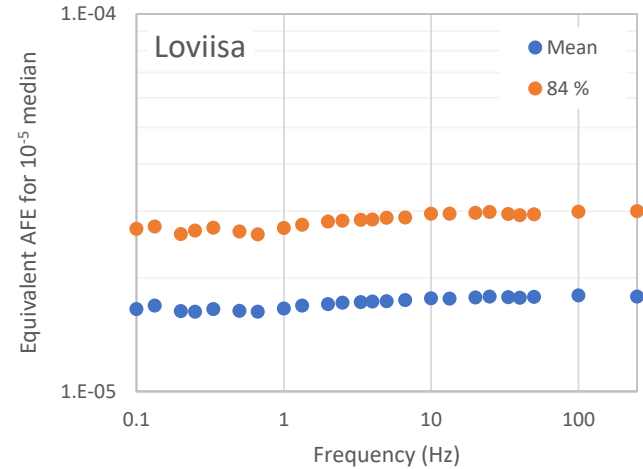
Processing of the hazard curves

- We analyzed hazard components (e.g. mean, median etc.) of different frequency ranges (e.g. 100Hz, 25Hz, 5Hz and 1Hz) at different AFE's (e.g. 10^{-5} , 10^{-6} , 10^{-7}).
- We developed options for DBE and DEC C.
- We targeted to support STUK's guidelines in the future.



Results

- Calculated the target AFE with **mean and 84th percentile confidence** for maintaining the current hazard for DBE and DEC C.
- Analyses **show a variability** for different frequencies at the sites.
- For the DBE “mean equivalent” AFE would be **in the range of AFE $2 \cdot 10^{-5}$** , in most cases.



Conclusions

- Mean and fixed-confidence hazard can be used when a single definition of seismic levels is needed.
- We recommend that PSHA output should be reported for mean, median, and the 5th , 16th , 84th and 95th fractile hazard to allow decision-making and comparison of modelled uncertainties.
- Depending on the targeted level of conservatism, e.g. a mean confidence AFE below $1.3 \cdot 10^{-5}$ would preserve the current hazard level for DBE at all sites.

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