Evolving the Fennoscandian GMPEs (SAFIR/EVOGY) and Synthetic ground motions (NKS/SYNTAGMA)

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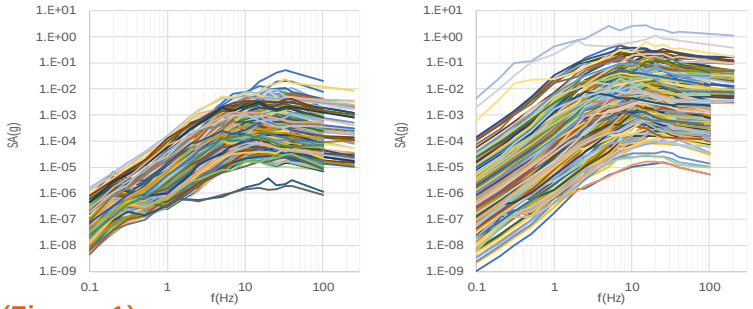
Aim of EVOGY and SYNTAGMA

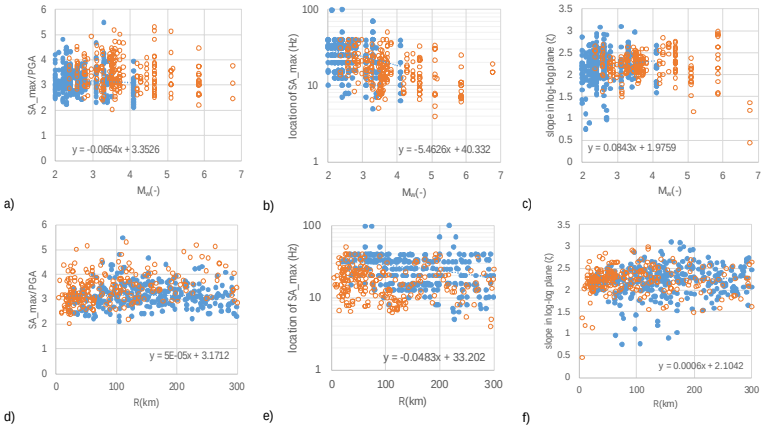
- Develop a ground motion prediction equation (GMPE) for probabilistic seismic hazard analyses (PSHA) of Finnish NPPs and to compute synthetic ground motions.
- Are there no GMPEs already?
  - There are. They are regional. For SCR and very hard rock not many. In Finland Varpasuo, Nikkari, Saari (2001) and Vuorinen (2015) were used.
- So why develop a GMPE? Is this repeating old work?
  - (1) Better measured data available. E.g. largest recorded event, the Gulf of Bothnia earthquake 2016 M_L 4.1 measured by the national and Fennovoima Oy seismic network. (2) The understanding of earthquakes and PSHA evolved. (3) Synthetic ground motions mature to be used in GMPEs.

Work in EVOGY (SAFIR2018)

- Collected/archived Fennoscandian recordings and created a spectra database for engineering evaluation (Figure 1).
- For the GMPE we used a combined dataset of Fennoscandian and NGA-East data for rock.
- Analyzed the key control parameters of the spectra (Figure 2).
- Adjusted the G16 GMPE for lower magnitudes and hard rock, while keeping the prediction unchanged where we have no data.



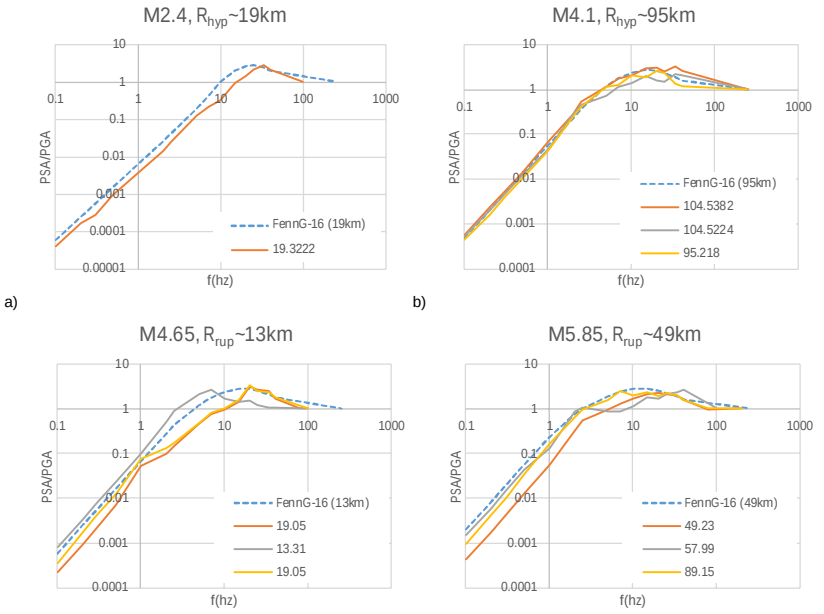
(Figure 1)



(Figure 2)

What is different about this GMPE

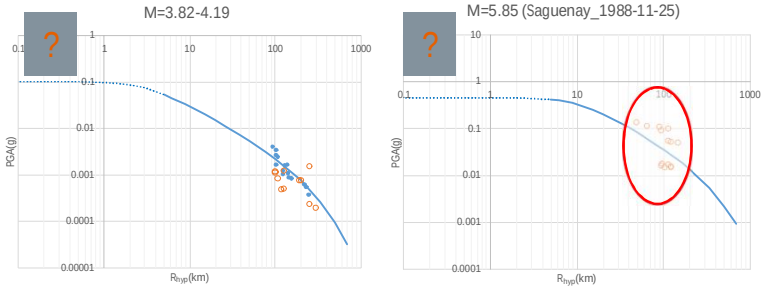
- It is modular, predicting PGA and spectra shape Sa_{norm} (Figure 3) separately. Other GMPEs predict SA for individual frequencies.
- PGA and SA_{norm} predictions modular by employing filters corresponding to attenuation effects. Good because we have little data; empirical GMPE is not feasible.
- For $2 \leq M_w \leq 7$ and $0 \leq R_{rup} \leq 300$km in Finland. Standard deviation (σ) 0.34~0.39 in $\log_{10}(SA)$ units.



(Figure 3)

The biggest challenge…

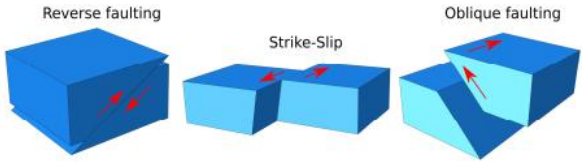
- No data in the near-field; closest recording is R_{rup}=19km for a M_L2.4. We do not know how to plateau the GMPE at short distances (Figure 4).
- In SYNTAGMA we created synthetic ones by modeling to complement measured ground motions.
- So we can model M_w's as we want (Figure 5) and plant observations points (Figure 6)



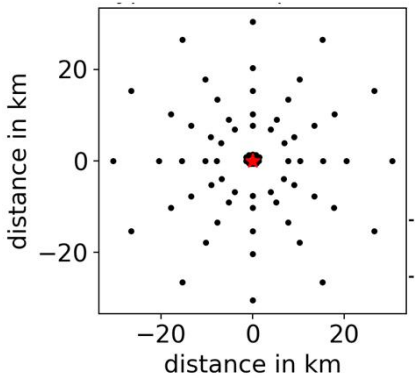
(Figure 4)

Moment magnitude (M_w)	Fault dip angle (deg)	Hypocenter depth (km)	Focal mechanism
4.3	30, 80, 45	2, 10	Reverse, Strike-Slip, Oblique
5.0	30, 80, 45	10	Reverse, Strike-Slip, Oblique
5.4	80, 45	10, 20	Strike-Slip, Oblique
5.5	30	10, 20	Reverse
5.6	30, 80, 45	10, 20	Reverse, Strike-Slip, Oblique

(Figure 5a)



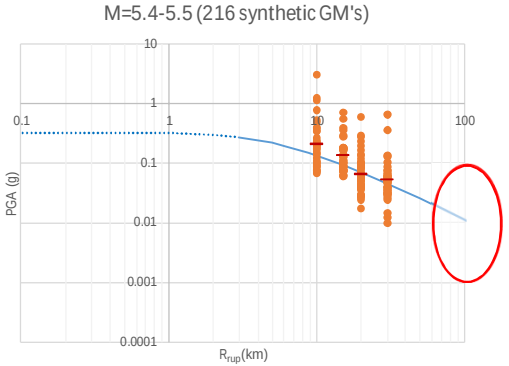
(Figure 5b)



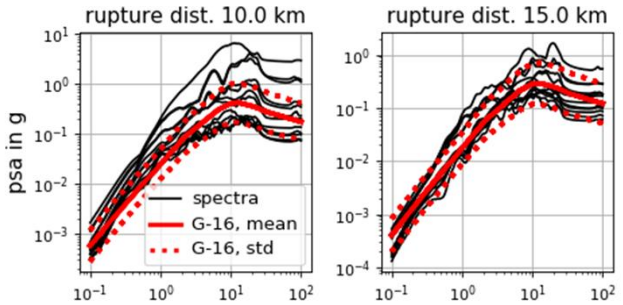
(Figure 6)

How to do it and outcome

- Earthquake sources generated by dynamic rupture modelling (3DEC).
- Time-slip functions transferred to Compsyn and ground motion calculated by point source summation of kinematic slip and complete Green's function.
- Ground-motion to 30 km; 25 Hz (*for now!*). PGA and spectra compared to G16 GMPE (Figure 7&8).
- Near-field PGA and spectra measure up reasonably.
- We will also be able to confirm the near-field prediction, or adjust the GMPE in the near range!



(Figure 7)



(Figure 8)

Acknowledgements
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