Evolving the Fennoscandian GMPEs (EVOGY)

Ludovic Fülöp[1], Vilho Jussila[1], Riina Aapasuo[2], Tommi Vuorinen[2], Päivi Mäntyniemi[2]

[1] VTT Technical Research Centre of Finland Ltd

[2] Institute of Seismology, University of Helsinki

Abstract

We propose a ground motion prediction equation (GMPE) for probabilistic seismic hazard analyses (PSHA) of Finnish NPPs. We collected and archived recordings of earthquakes in Fennoscandia and created a database with spectral components important for engineering evaluation.

For developing the GMPE we used a combined dataset of Fennoscandian and NGA-East data for very hard rock. We used the backbone curve of the G16 GMPE by Graizer (2016) and adjusted the peak ground acceleration (PGA) prediction to cover lower magnitudes, while keeping it unchanged above M_w4. We also adjusted the normalized spectral shape (SA_{norm}) prediction using the combined dataset. We evaluated the mean prediction and error. We used a synthetic ground motions created using a hybrid modeling method to confirm the prediction in the near-field.

We conclude that the GMPE formulation is adequate for predicting ground motions in Fennoscandia in the range of $2 \le M_w \le 7$ and $0 \le R_{rup} \le 300$km on hard-rock. The standard deviation of the prediction error (σ) is in the range of 0.34~0.39 in $\log_{10}$(SA) units for relevant frequencies.

Methods

For the adaptation of G16 we have the following possible data sources:

- Fennoscandian earthquake catalog (90 events, $2.0 \le M_L \le 4.2$);
- East-Canadian subset of the NGA-East data. Some earlier used in Finland (Varpasuo *et al*, 2001). Magnitudes up to $M_w \le 6.76$;
- Recordings of induced earthquakes in southern Finland ($1.4 \le M_L \le 1.7$, sampling 500Hz, $R_{epicentre}$<10km);
- Synthetic ground motions from modelling of earthquakes $4.3 \le M_w \le 5.6$, $0 \le R_{rup} \le 30$km, (Fülöp *et al*, 2018).

Like in G16, we predict PGA and spectra shape individually (Eq.1). We derive the hard-rock (V_{s30}=2800m/s) PGA from the data.

$$SA(T)_{FennG16} = PGA_{FennG16} \times SA_{norm} \quad (1)$$

The normalized shape of the spectra is estimated separately, respecting the mathematical form of G16 (Eq. 2):

$$SA_{norm} = I \times \exp\left[-0.5 \times \left(\frac{\ln(T)+\mu}{S}\right)^2\right] + \frac{1}{\sqrt{\left(1-\left(\frac{T}{T_{sp,0}}\right)^{\xi}\right)^2 + 4\times {D_{sp}}^2 \times \left(\frac{T}{T_{sp,0}}\right)^{\xi}}} \quad (2)$$

The use of normalized spectral shape is justified, both when comparing the spectra (Figure 1) and when we study the control properties of the spectral shape (Figure 2).

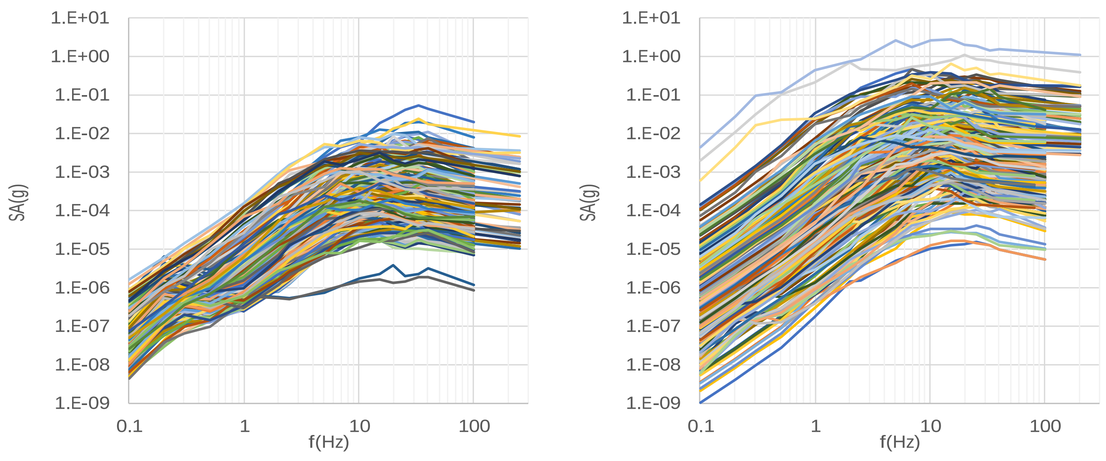

Figure 1. Acceleration spectra (RotD50) of the Fennoscandian dataset (a) and of the NGA-East hard rock subset. The Fennoscandian set has some anomalous peaks below 1Hz

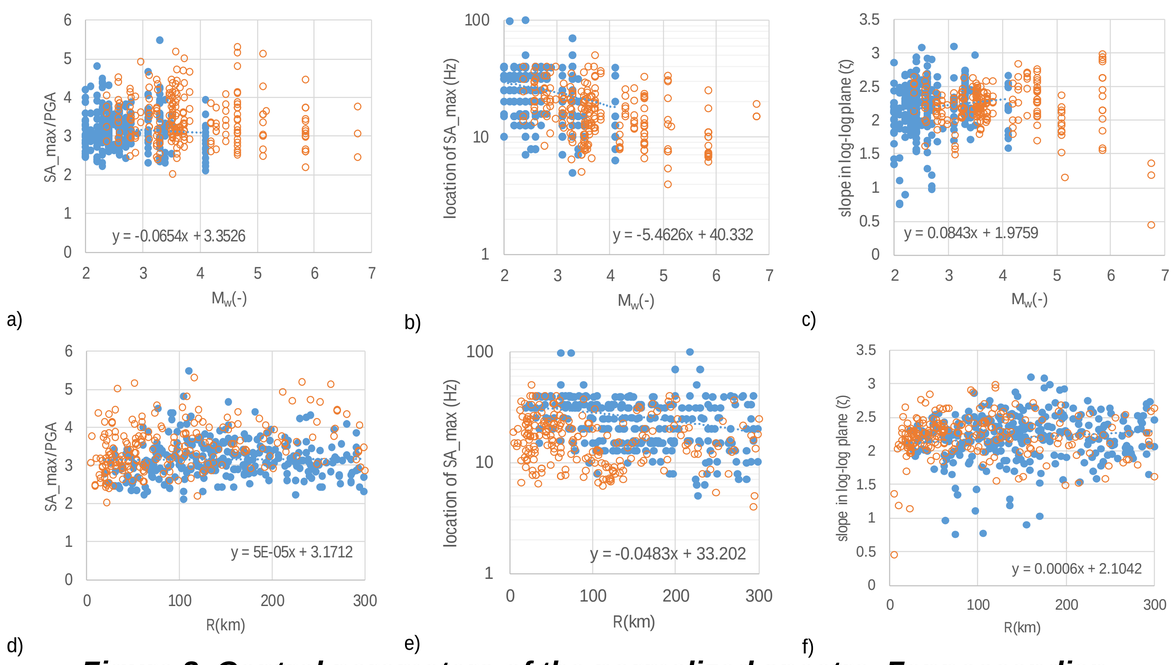

Figure 2. Control parameters of the normalized spectra. Fennoscandian dataset (blue circles) and NGA-East subset (orange circles). Amplification (SA_{max}/PGA) with a mean of ~3 (a,d), the frequency of the spectra peak (SA_{max}) (b, e) and the slope at low frequencies ~2 (c, f).

Results

In Figure 3 we exemplify the differences between the spectral shapes of selected near-field data and the predicted SA_{norm}.

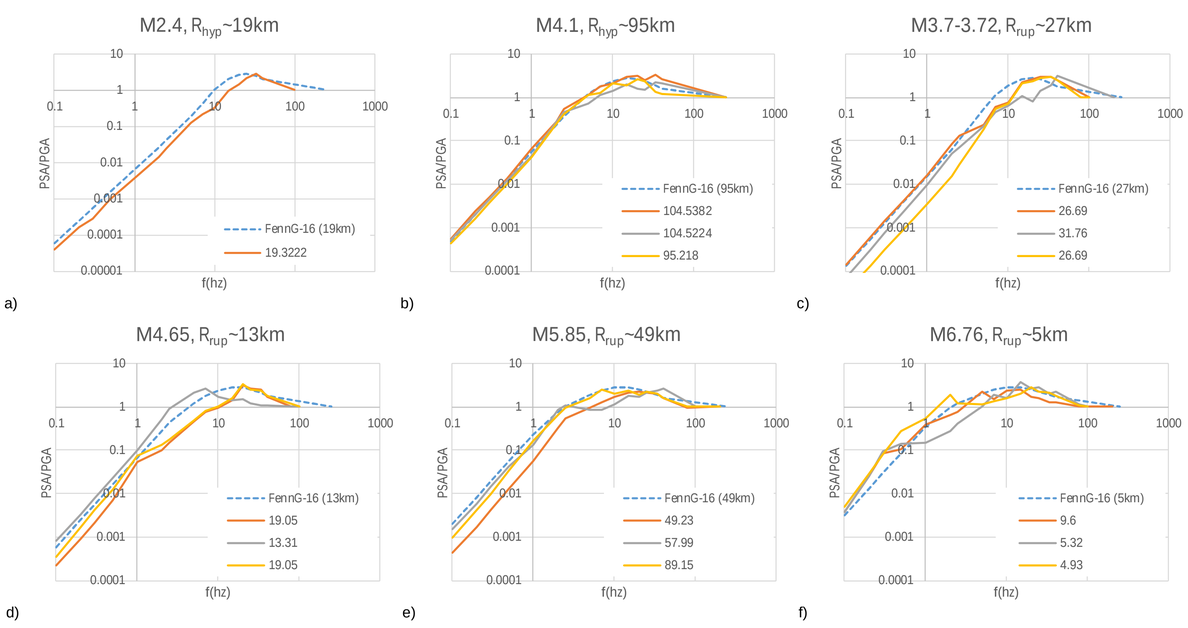

Figure 3. Comparison of SA_{norm} with selected spectra from the Fennoscandian dataset. a) from a 9/27/2008 event with depth=17.3km, b) the Gulf of Bothnia earthquake of 2016-03-19 depth=23.5km; and from the NGA-East dataset. Spectra are from the c) Baie St. Paul, 2006-04-07, d) Riviere Du Loup, 2005-03-06, e) Saguenay, 1988-11-25 and f) Nahanni, 1985-12-23 earthquakes

We obtain a composite prediction with the median and standard deviation of $\log_{10}$(Res) given in Table 1 (Res = $SA_{prediction}/SA_{data}$). The GMPE follows the data in the range of 1-40 Hz. The largest standard deviation in this range is σ=0.39 $\log_{10}$ units. The errors below 1 Hz are not so relevant, since they reflect the anomalous peaks in the Fennoscandian spectra which we think are not part of event induced ground motion (Figure 1a).

Table 1. Median of Res and standard deviation of $\log_{10}$(Res) of the GMPE

f(Hz)											
0.1	**0.3**	**0.5**	**1**	**2**	**5**	**10**	**15**	**20**	**25**	**33.3**	**40**
-0.31	-0.38	-0.13	-0.02	-0.07	-0.06	0.041	0.052	0.04	0.005	-0.09	-0.12
0.53	0.55	0.37	0.34	0.34	0.34	0.34	0.36	0.38	0.39	0.37	0.37

Conclusions

- **We propose an adaptation of the G16 GMPE for Fennoscandia**
- **We separate the prediction of PGA and the normalized spectral shape (SA_{norm}) to keep the GMPE modular. The SA_{norm} prediction is remarkably good, especially for 5-40Hz.**
- **We demonstrate compatibility between the Fennoscandian and NGA-East (Canadian) spectra, not explored at this scale.**

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Contact

Ludovic Fülöp

Tel. +358 40 593 4698, ludovic.fulop@vtt.fi