When 1D Response Analysis Fails: Application of Earthquake HVSR in Site-Specific Amplification Estimation

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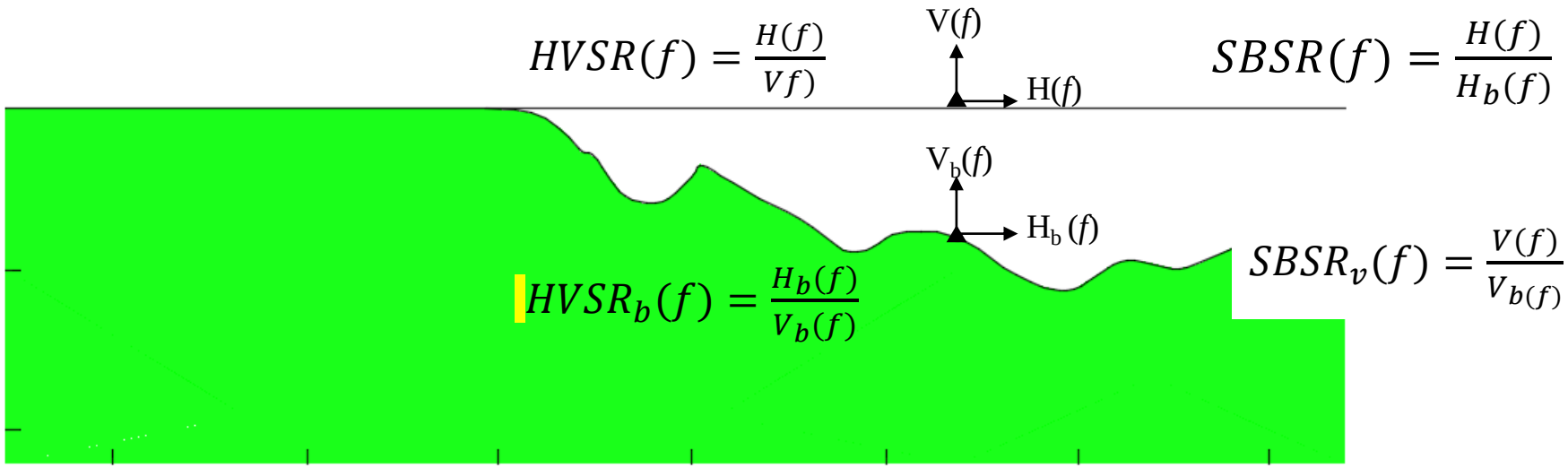
Empirical Correction to HVSR



$$HVSR(f) = \frac{H(f)}{H_b(f)} \cdot \frac{H_b(f)}{V_b(f)} \cdot \frac{V_{b(f)}}{V(f)} = \frac{HVSR_b(f)}{SBSR_v(f)} \cdot SBSR(f)$$

$H_b(f)=V_b(f)$ or $HVSR_b = 1.0$

$$SBSR(f) = HVSR(f) \cdot SBSR_v(f)$$

$$\boldsymbol{pSBSR(f) = HVSR(f) \cdot < SBSR_v(f) >}$$

Data Selection

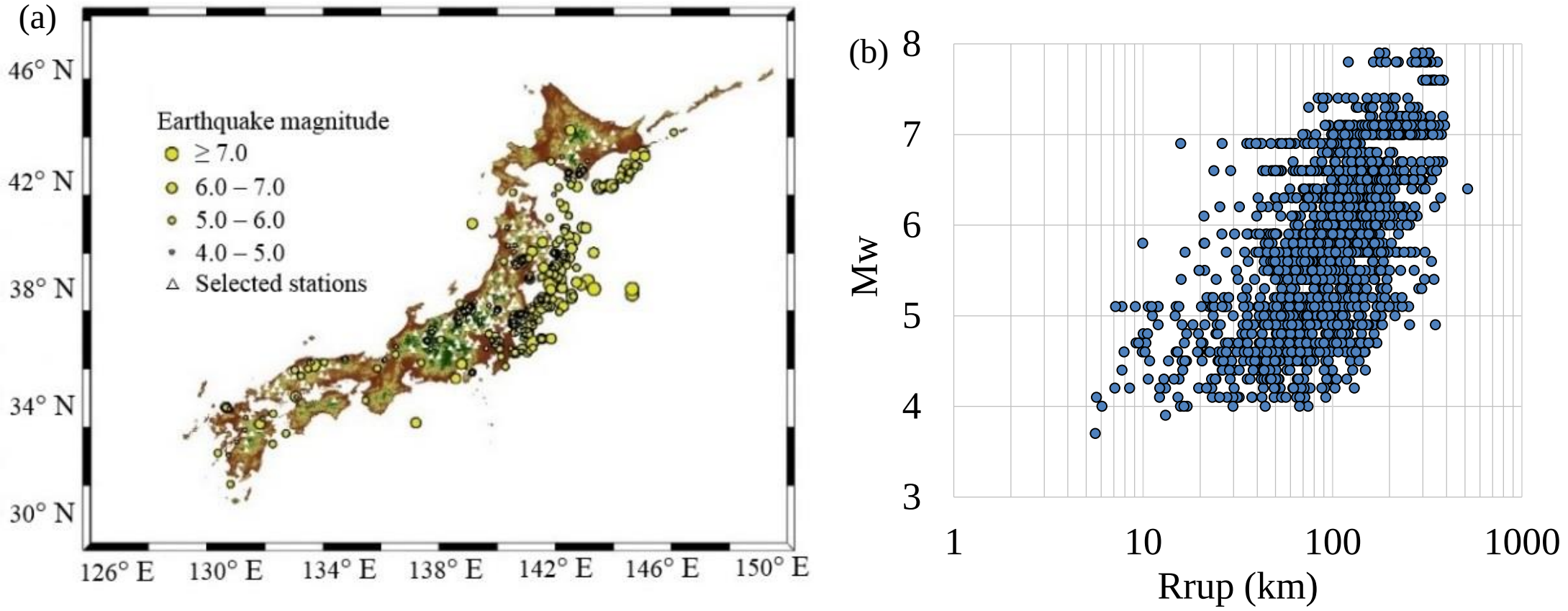


Fig. (a) Spatial distribution of earthquakes and 207 KiK-net stations used in this study, and (b) Mw-Rrup distribution of the 1840 selected earthquake recordings.

Correction Spectra

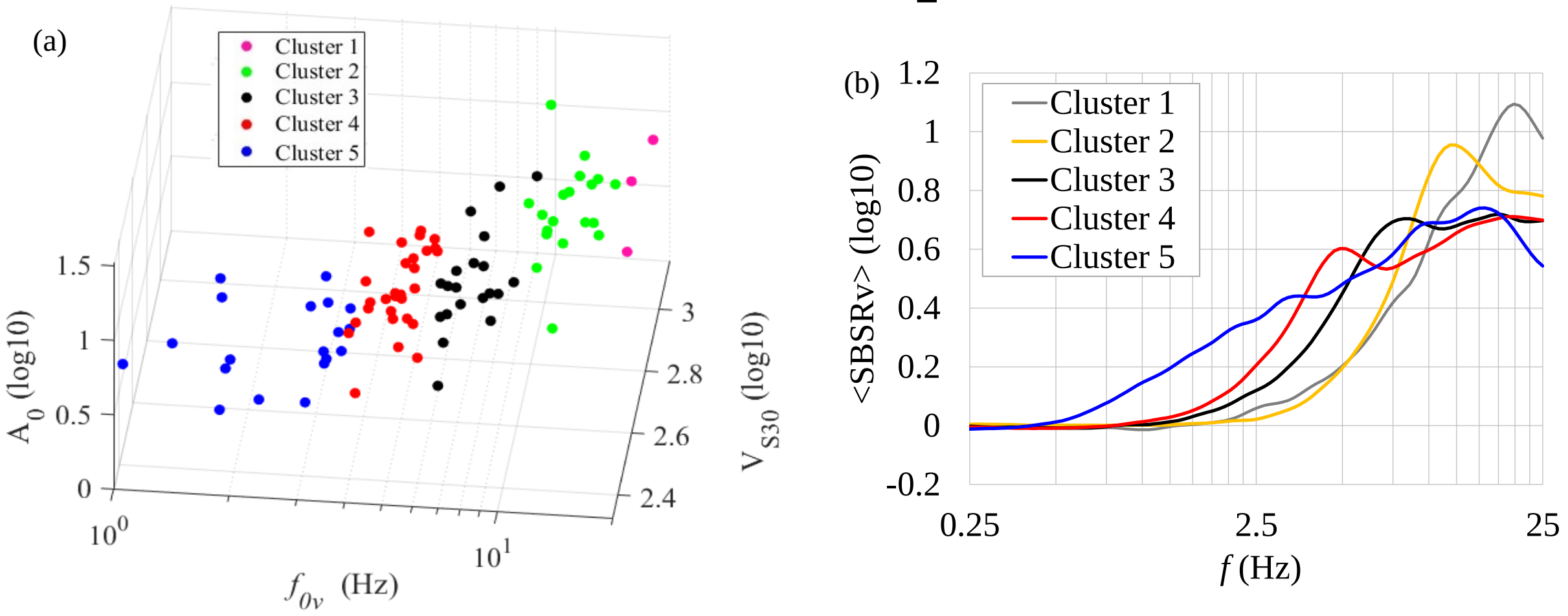


Fig. (a) k-means clustering of the 90 KiK-net sites, and (b) average SBSRv for each cluster, i.e., <SBSRv>.

Correction Spectra

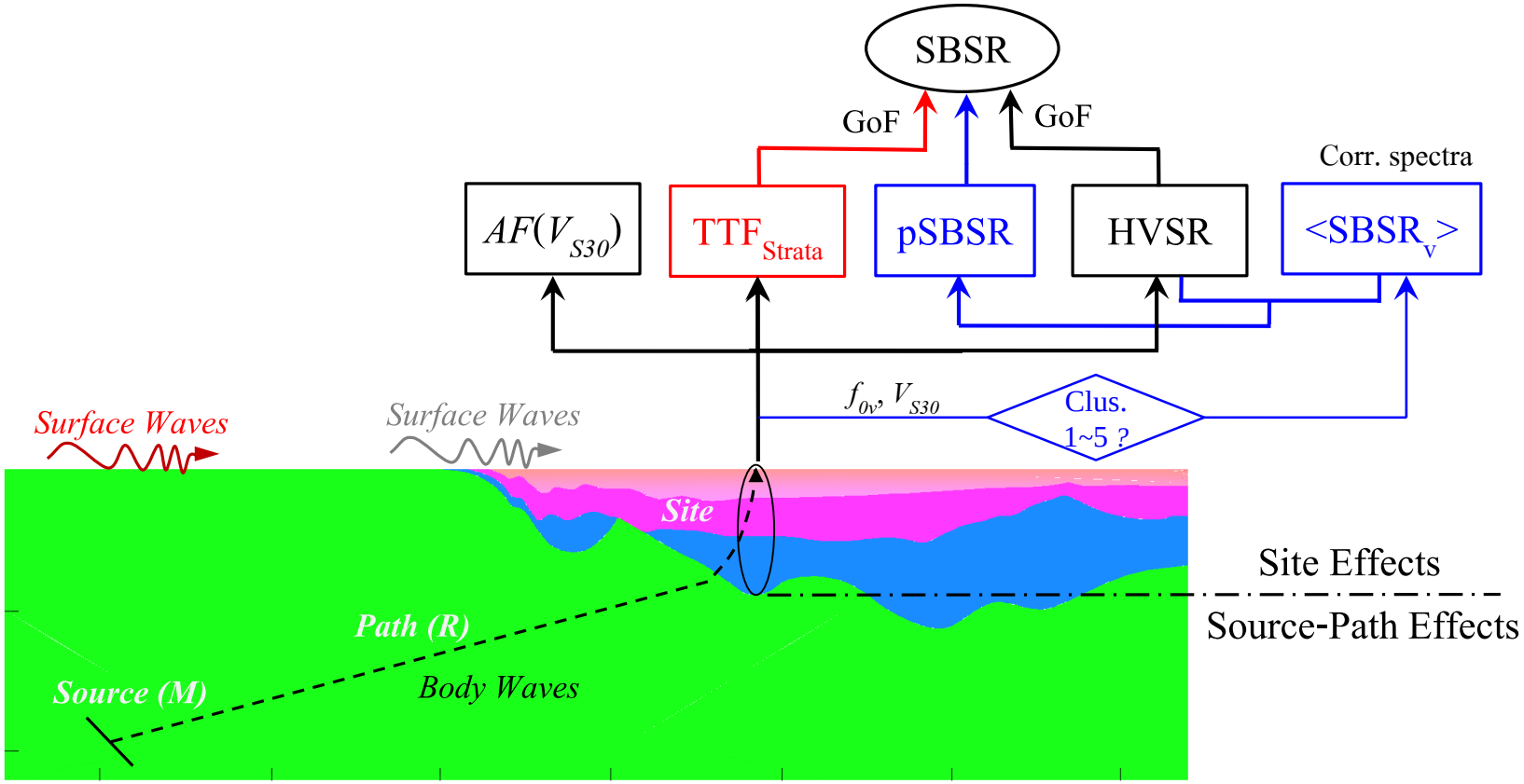


Fig. Evaluation of techniques used in site effects quantification.

pSBSR vs. TTF

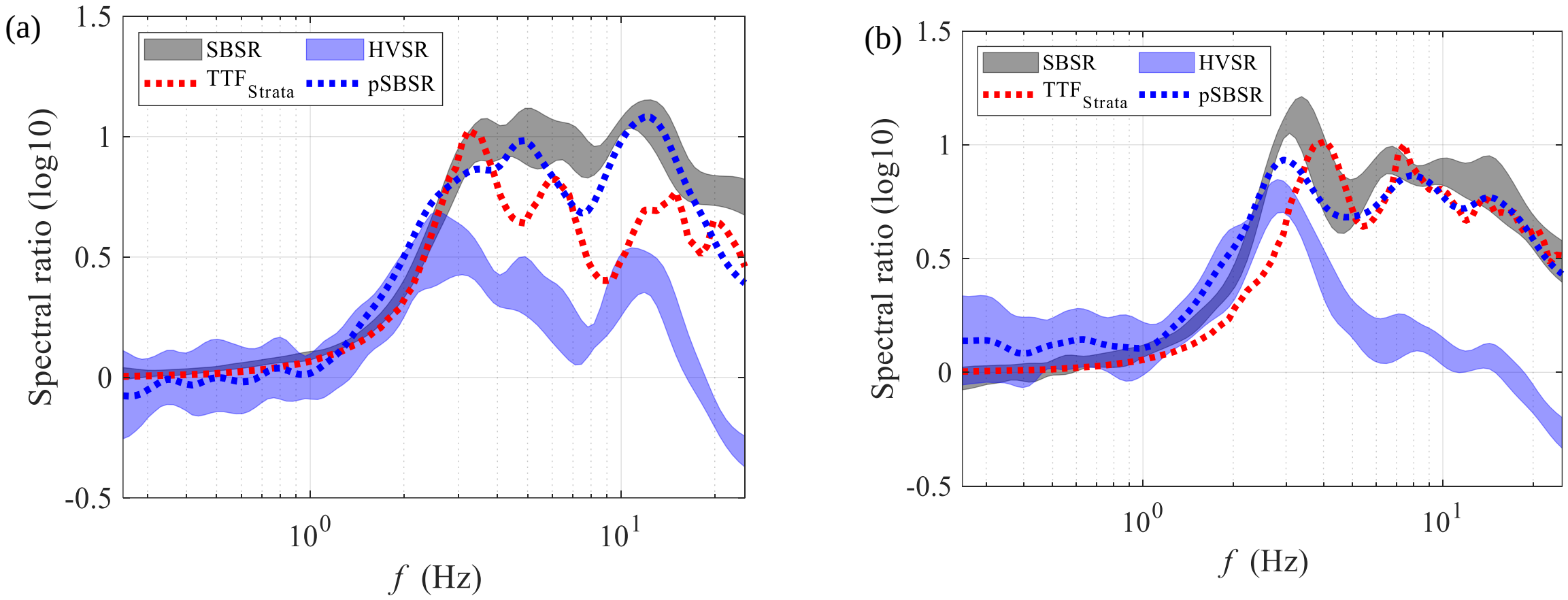


Fig. HVSR, TTFStrata and pSBSR at sites (a) TCGH07 and (b) IWTH04.

Goodness-of-fit (GoF) metrics

Goodness-of-fit metric	Expression	Range	Measure	Interpretation
Pearson's r	$\frac{\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i-\bar{y})^2}}$	[-1, 1]	Linear relationship	Measure the closeness in shape (alignment of peaks and troughs)
Spearman's ρ	$\frac{cov(rg_x, rg_y)}{\sigma_{rg_x}\sigma_{rg_y}}$	[-1, 1]	Ordinal relationship	
Kendall's τ	$\frac{2[\sum_{i<j} sgn(x_i-x_j)sgn(y_i-y_j)]}{n(n-1)}$	[-1, 1]	Ordinal relationship	
Index of Agreement d	$1-\frac{\sum_{i=1}^{n}(x_i-y_i)^2}{\sum_{i=1}^{n}(\lvert y_i-\bar{x}\rvert+\lvert x_i-\bar{x}\rvert)^2}$	[0, 1]	Degree of difference (relative)	Measure the difference in amplitude
Mean Absolute Error MAE	$\frac{\sum_{i=1}^{n}\lvert y_i-x_i\rvert}{n}$	-	Degree of difference (absolute)	

pSBSR vs. TTF

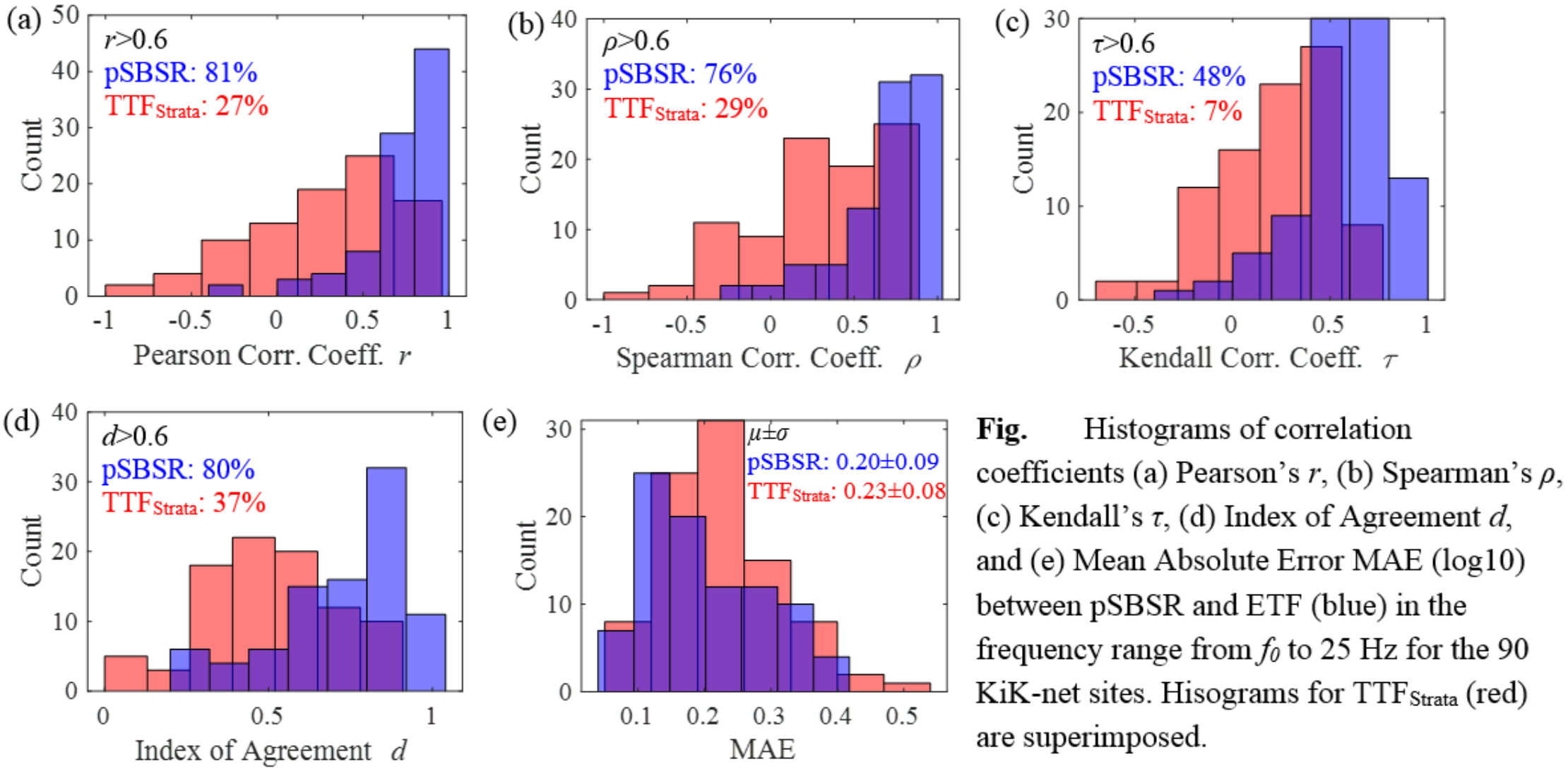


Fig. Histograms of correlation coefficients (a) Pearson's r, (b) Spearman's ρ, (c) Kendall's τ, (d) Index of Agreement d, and (e) Mean Absolute Error MAE (log10) between pSBSR and ETF (blue) in the frequency range from f_0 to 25 Hz for the 90 KiK-net sites. Hisograms for TTF_{Strata} (red) are superimposed.

pSBSR vs. TTF

Table. Success rates of TTFStrata and pSBSR in reproducing SBSR under different definitions of “good match”

Estimation	$r>0.60$	$r>0.60$ $d>0.60$	$r>0.65$ $d>0.65$	$r>0.60$ MAE<0.25	$r>0.65$ MAE<0.20
TTF	27%	27%	18%	22%	14%
pSBSR	81%	76%	68%	62%	50%

Summary

The empirical correction to HVSR is highly effective and achieves a “good match” in both spectral shape and amplitude at the majority of the 90 KiK-net sites, as opposed to less than one-third for the 1DSH modelling. In addition, the empirical correction does not require a ground model as GRA and thus has great potentials in seismic hazard assessments.

Thank you very much!