Stiffness effect for sites in CENA, starting with fpeak

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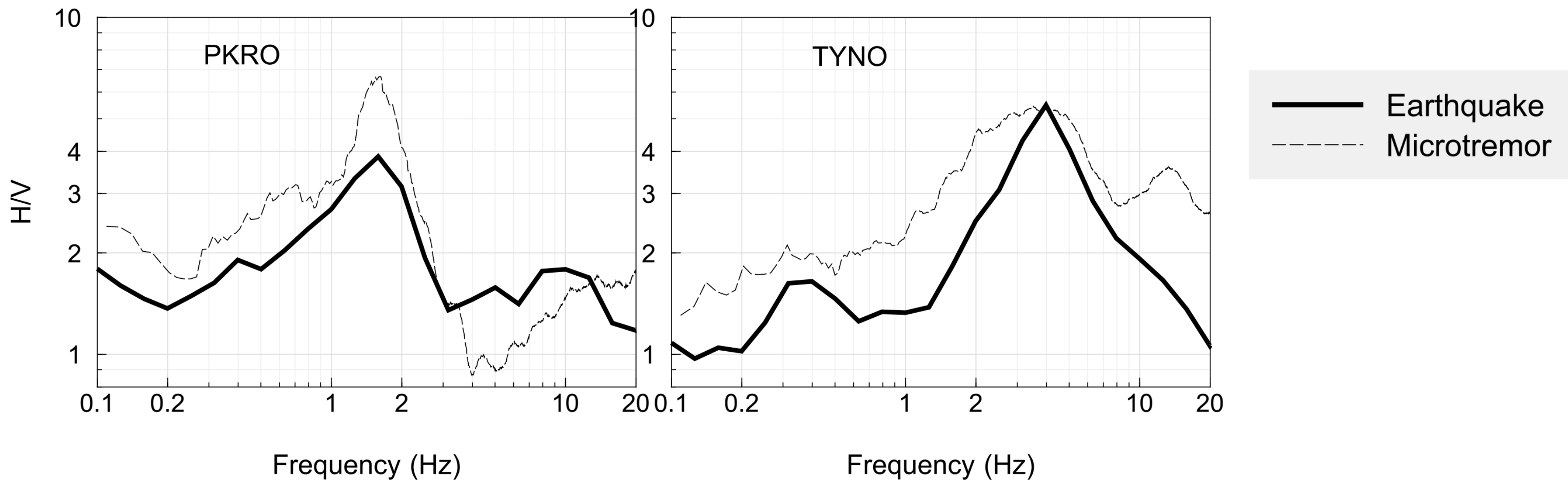
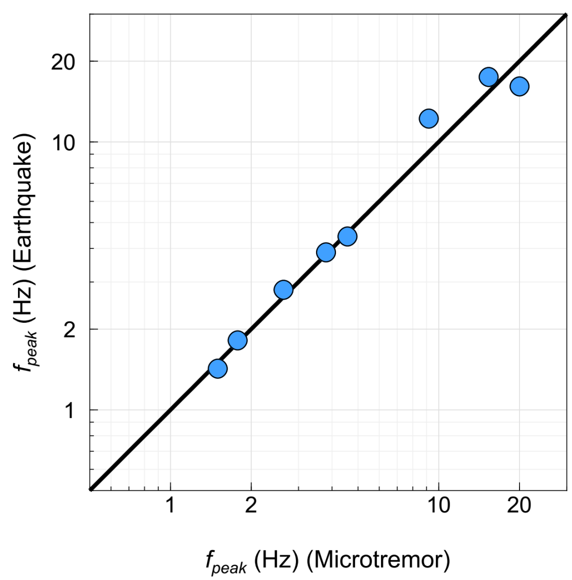
fpeak from Microtremor survey vs. Earthquake H/V





Microtremor survey in southern Ontario for 8 seismic stations.

Hassani and Atkinson (2016) presented an f_{peak} -based site-amplification model

- no stiffness scaling term in our 2016 model
- Here we look at the stiffness effect on the amplification of sites in CENA.
- In the first step, we first remove the fpeak-based amplification model from the observe data, and then look at the residual site terms with respect to VS30.

- In order to do that, we first calculate the residuals with respect to SOSN GMPE model (Atkinson et al., 2015) using the site-effects model developed wrt hard-rock site conditions , and then define the site terms with respect to hard-rock site condition.

$$re_{ij,SOSN} = S_{j,SOSN} + \eta_i + \varepsilon_{ij}$$

Finding Residual Site terms

$$log(re_{ij,SOSN}) = log(obs_{ij}) - log(pre_{ij,SOSN}) - C_S(f, f_{peak,j})$$

$$\log(re_{ij,SOSN}) = S_{j,SOSN} + \eta_i + \varepsilon_{ij}$$

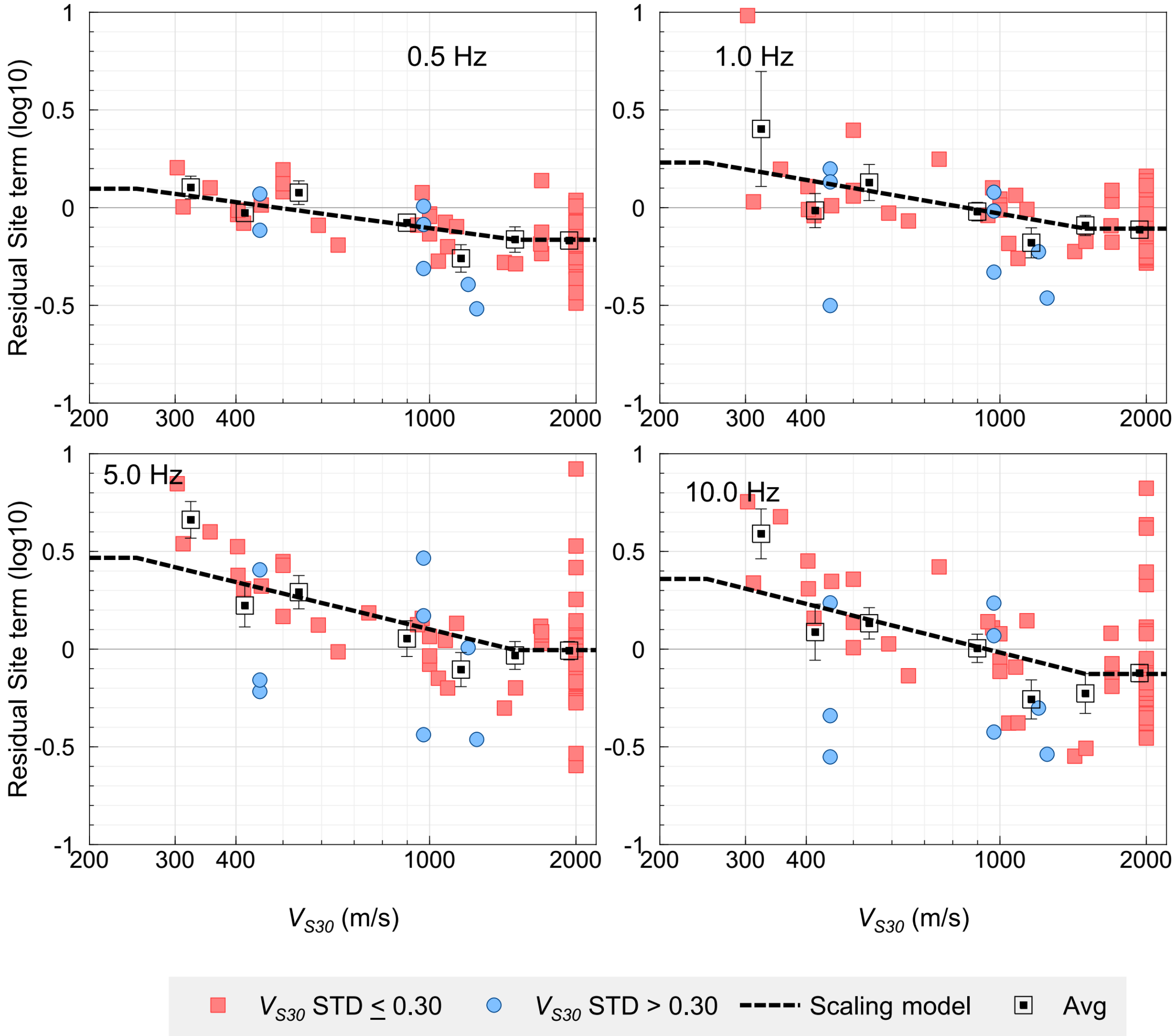
where $log(re_{ij,SOSN})$ is the residual for event i at station j;
$log(obs_{ij})$ is the observed data for event i at station j,
$\log(pre_{ij,SOSN})$ is the prediction from the SOSN GMPE model for event i at station j;
and $C_S(f, f_{peak,j})$ is the amplification for station j with respect to hard-rock site condition (equation 3 in Hassani and Atkoinson 2016).
$S_{j,SOSN}$, is the average residual site term for station j,
η_i is the inter-event error for event i,
and ε_{ij} is the intra-event error for event i at station j.

We also include sites with VS30> 1500 m/s and no observed fpeak values. For these sites, we assume that the fpeak value is higher than 20 Hz.

VS30 Scaling term

We use Parker et al. (2016) updated VS30 values for our sites.

Glaciated



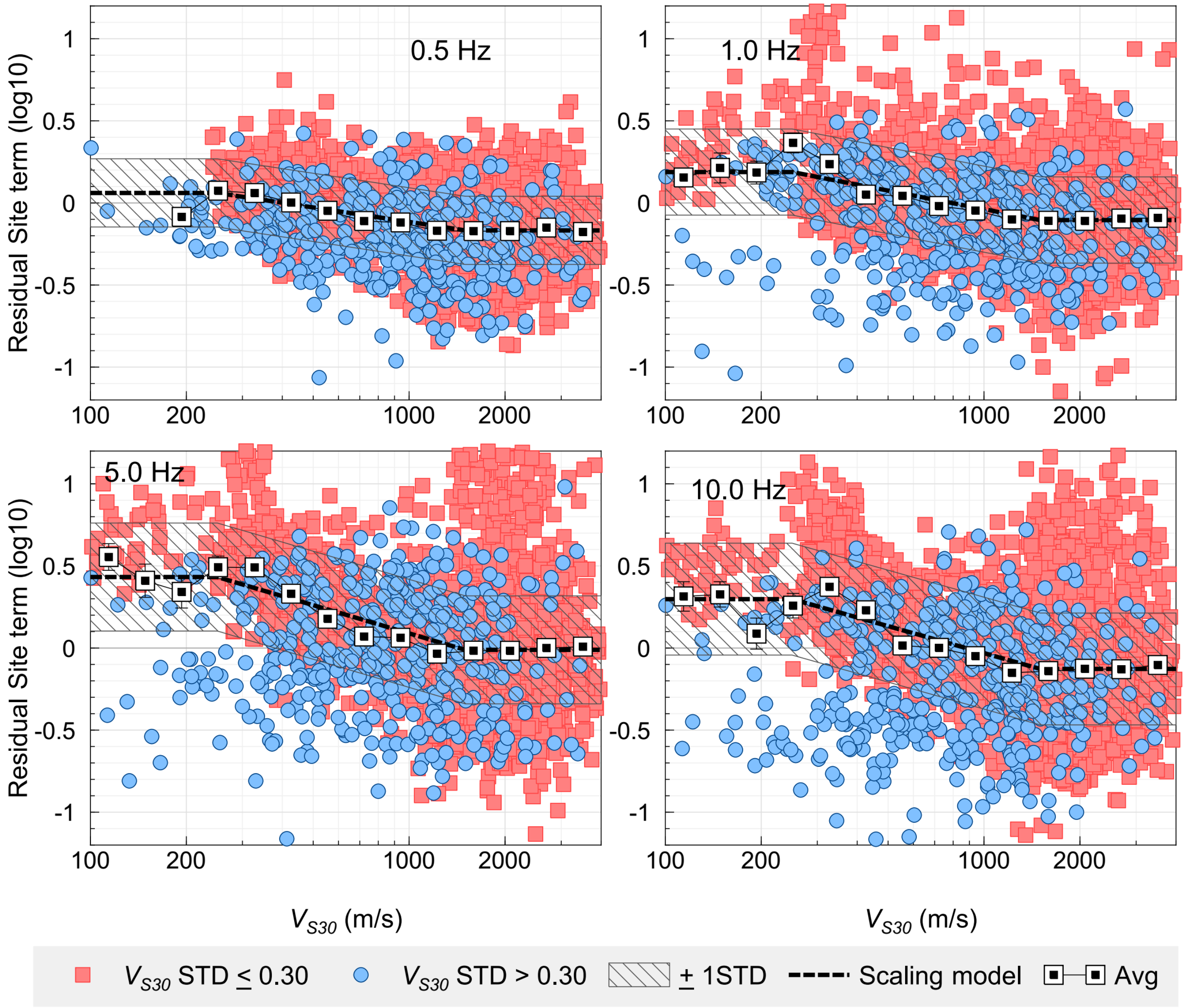
These are the apparent trends if we neglect uncertainty in VS30 estimates (VS30 variance)

VS30 Scaling term, applying Monte Carlo simulation

- In order to derive the right VS30-scaling model, it's corresponding standard deviation and also the standard error of the coefficients, we need to some how take account for the different variance in our VS30 estimates (e.g. different proxies have different estimate standard deviation).
- Moreover, each of the average residual site terms comes with a standard deviation too (e.g. we averaged residual site terms at each station with three or more records). We also need to take account for this variability in our VS30-Scaling model.
- The solution that we present here is to use Monte Carlo simulation to populate our data. For each of the data points ,we have a Vs30 estimate with an assigned standard deviation (e.g. log of Vs30), and also we have a standard deviation for each of the average residual site terms. We randomly generate 50 points for each of our data points assuming a normal distribution for log of VS30 and average residual site term ($S_{SOSN,j}$).

VS30 Scaling term, applying Monte Carlo simulation

Glaciated

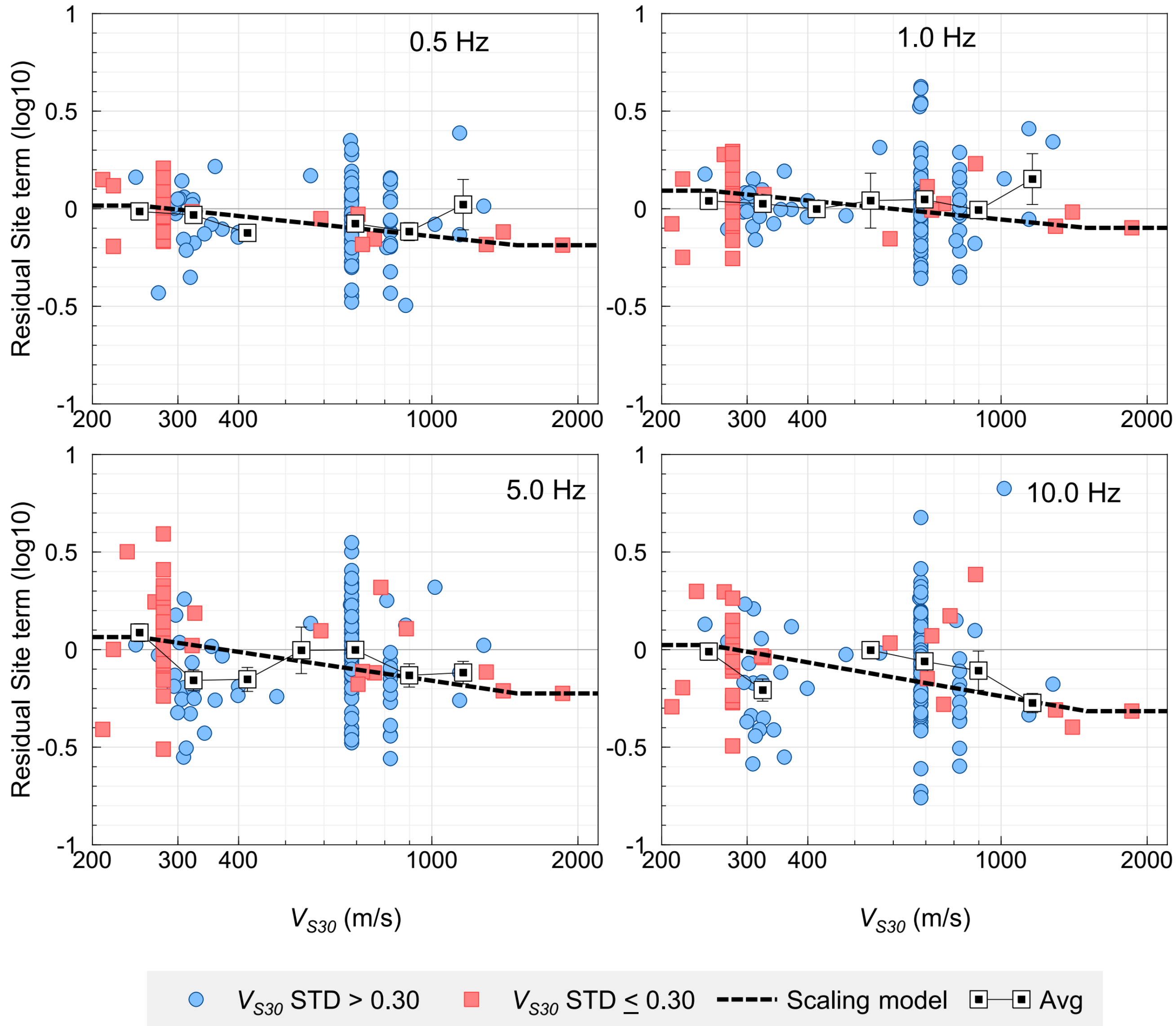


This trend accommodates the uncertainty for VS30 estimates and also for average residual site terms (normal distribution)

VS30 Scaling term

We use Parker et al. (2016) updated VS30 values for our sites.

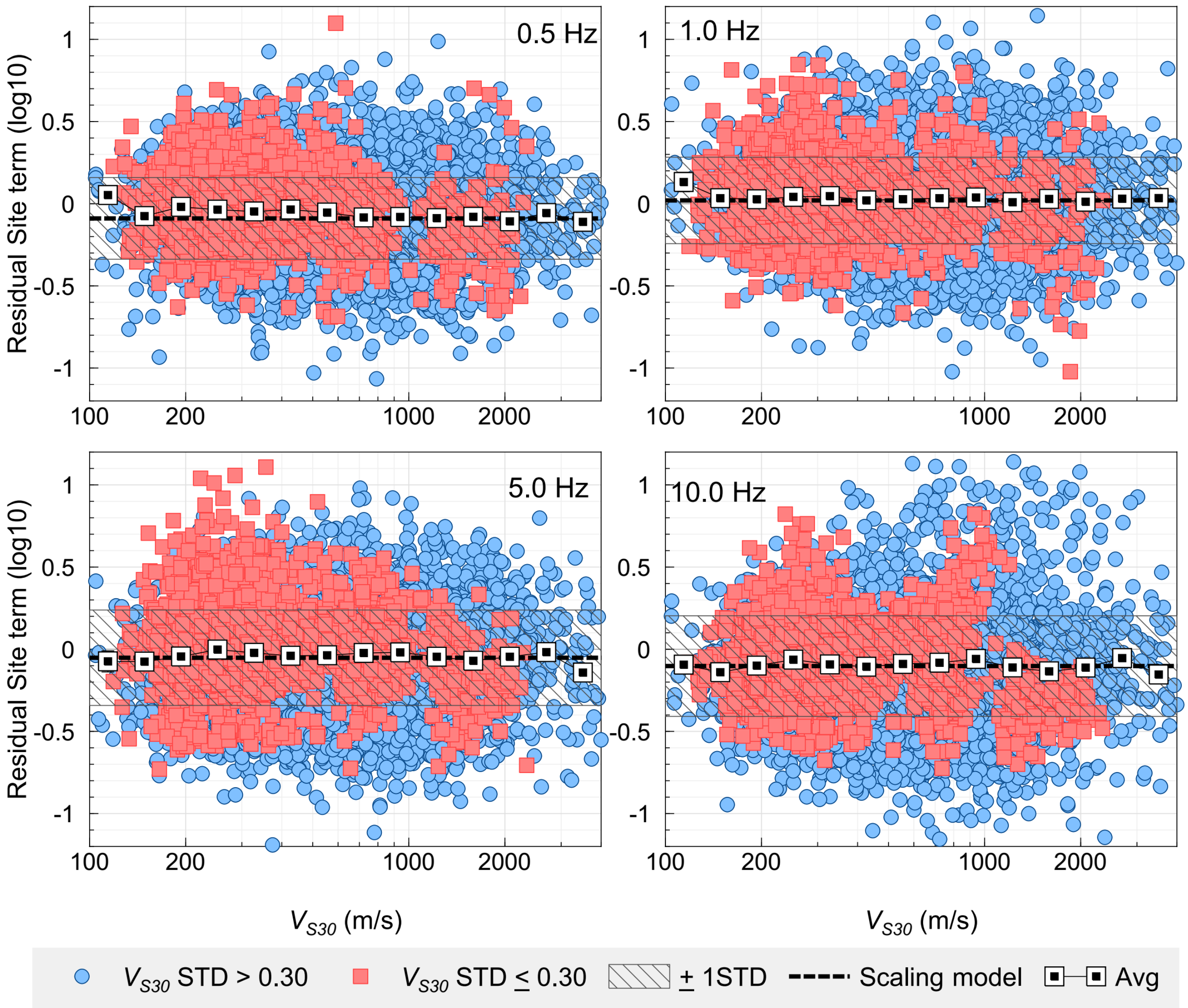
Non-Glaciated



Apparent trend neglecting uncertainty in VS30 estimates (VS30 variance)

VS30 Scaling term, applying Monte Carlo simulation

Non-Glaciated



Apparent trend considering uncertainty in VS30 estimates and also in average residual site terms

No obvious VS30-dependent trend due to large VS30 uncertainties!

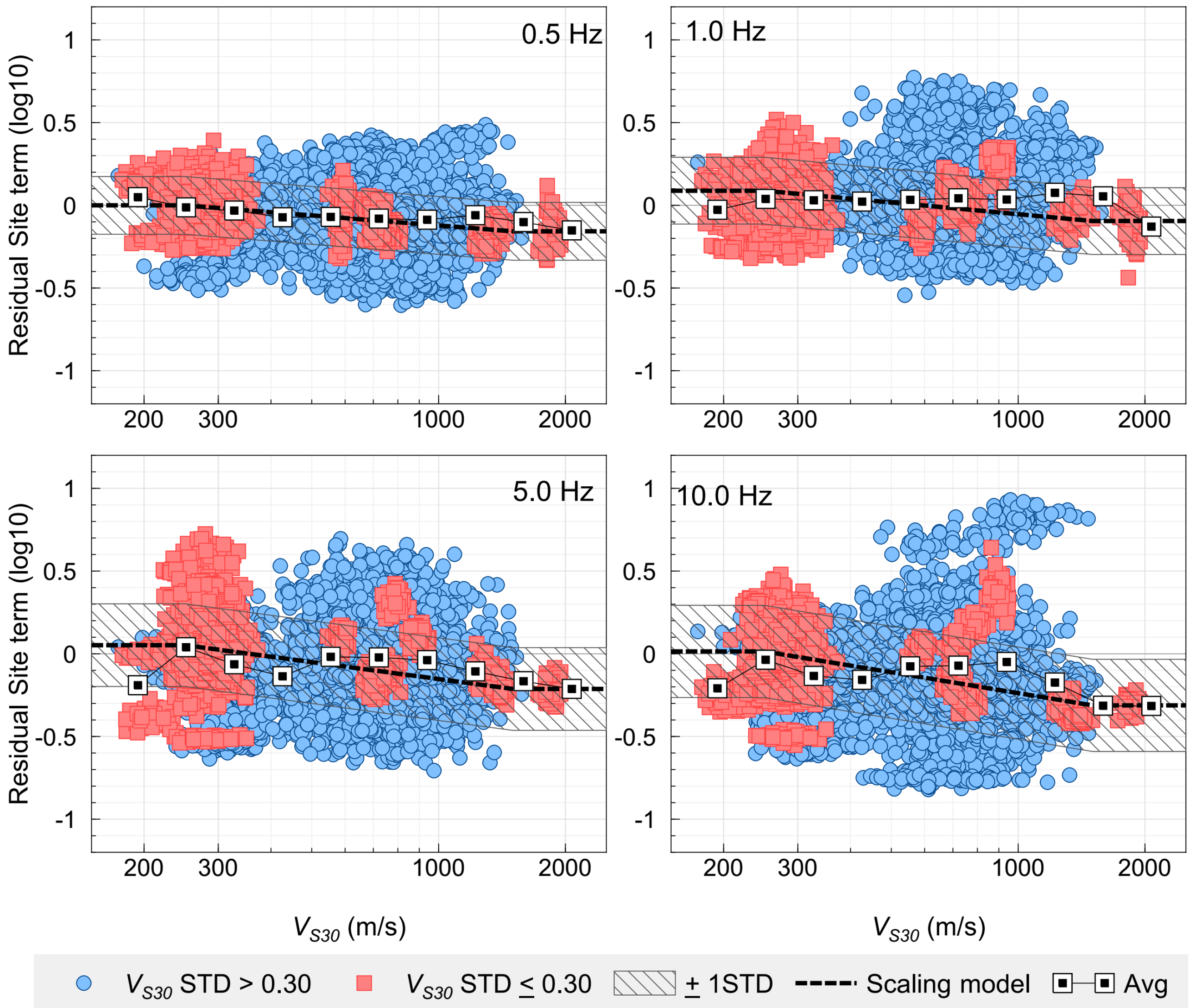
A consequence of large variance in VS30 estimates

Considering the variability of VS30 estimates can significantly change the average VS30-scaling model for non
aciated sites. The problem is that for some of the sites the variance on the VS30 estimates are very high (e.g. 0.85 in ln units), which can affect the average VS30 scaling model.

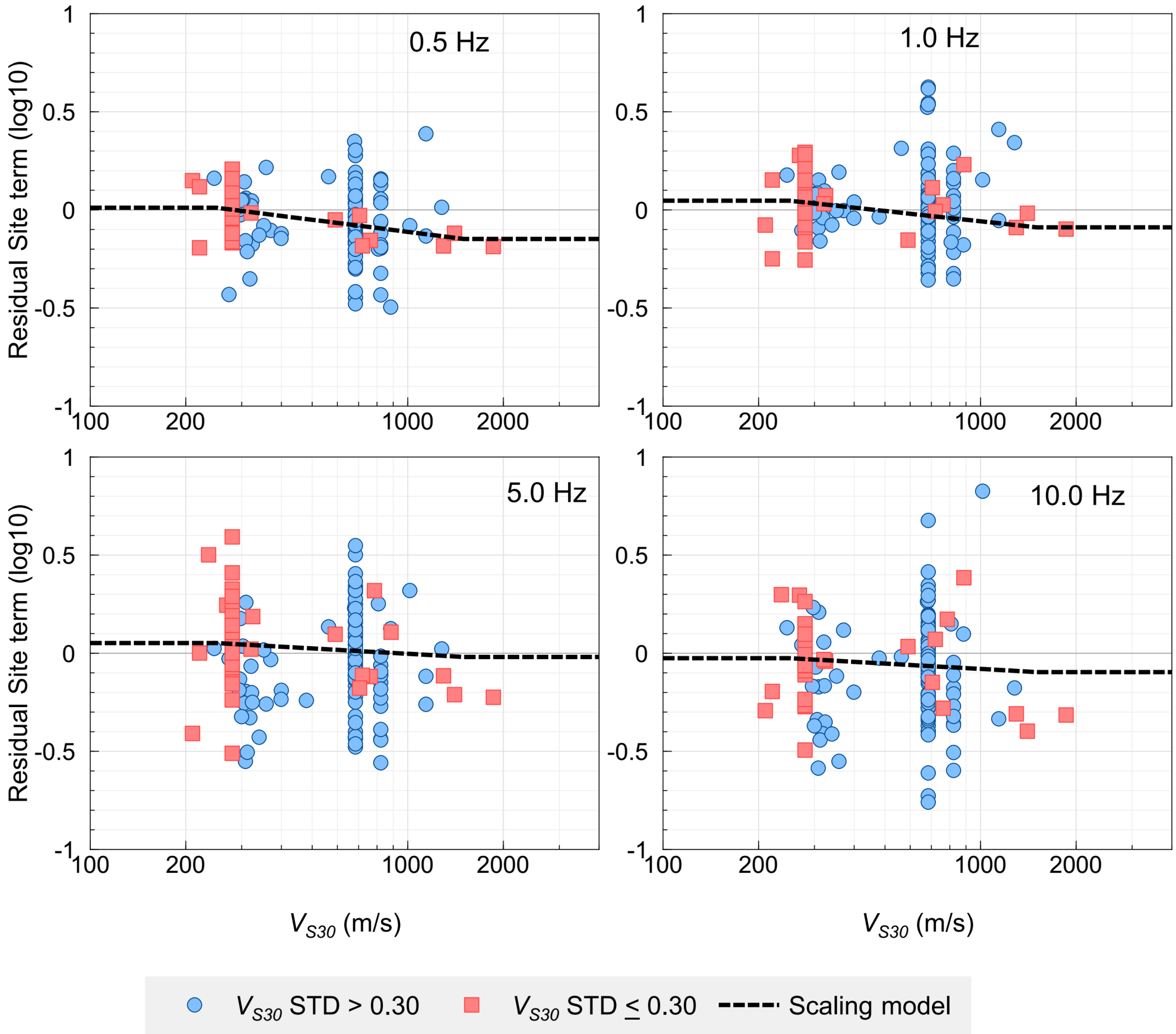
Here, we constrain our non-glaciated model based on the model that we developed for glaciated sites and we scale it to match the few non-glaciated data points with small VS30 standard deviation (<= 0.3). We assume that the scaling term for sites with VS30> 1500 m/s is the same as the glaciated model, and we fix the scaling term for sites with VS30 <250 m/s using the non-glaciated data points with VS30~ 300 m/s.

VS30 Scaling term, applying Monte Carlo simulation (0.3 sigma)

Non-Glaciated

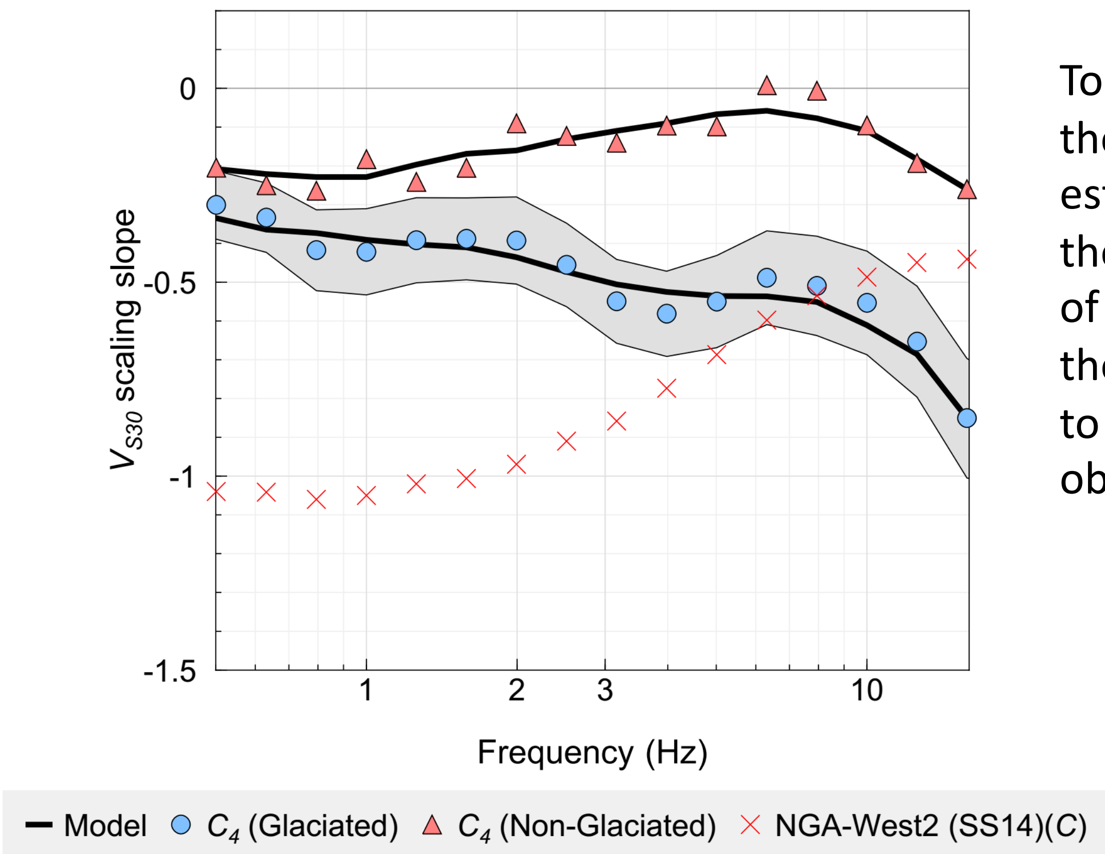


VS30 Scaling term, non-glaciated



Non-Glaciated scaling model derived based on the glaciated model and also data points with low VS30 variance.

C4, VS30 Scaling slope, Glaciated and non-glaciated



To derive the right standard error for the C4 term, we multiply the estimated standard error based on the populated database by a factor of 7 (square root of 50 (number of the random data points generated)), to correct it for the actual number of observations we have.

VS30 Scaling term

Based on the observed VS30-dependent trends, we derive two separate models for glaciated and non-glaciated sites.

$$F_S(f, V_{S30}) = \begin{cases} C_4 \log\left(\frac{250}{1500}\right) + C_5 & V_{S30} < 250 \\ C_4 \log\left(\frac{V_{S30}}{1500}\right) + C_5 & 250 \leq V_{S30} < 1500\ m/s \\ C_5 & V_{S30} \geq 1500\ m/s \end{cases}$$

where C4 is the VS30 scaling slope, and C5 is the average residual site terms for sites with VS30 $\geq$ 1500 m/s.

Fpeak and VS30 based amplification model

$$Amp\left(f, f_{peak}, V_{S30}\right) = C_s\left(f, f_{peak}\right) + F_S(f, V_{S30})$$

$$C_s\left(f, f_{peak}\right) = \begin{cases} C_1 & f_{peak} < 0.5\ Hz \\ C_1 + \left[\dfrac{C_2 - C_1}{log10(f/0.5)}\right] \times log10\left(f_{peak}/0.5\right) & 0.5\ Hz \leq f_{peak} < f \\ C_2 + \left[\dfrac{C_3 - C_2}{log10(20/f)}\right] \times \left[log10\left(f_{peak}/f\right)\right] & f \leq f_{peak} < 20\ Hz \\ C_3 & 20\ Hz \leq f_{peak} \end{cases}$$

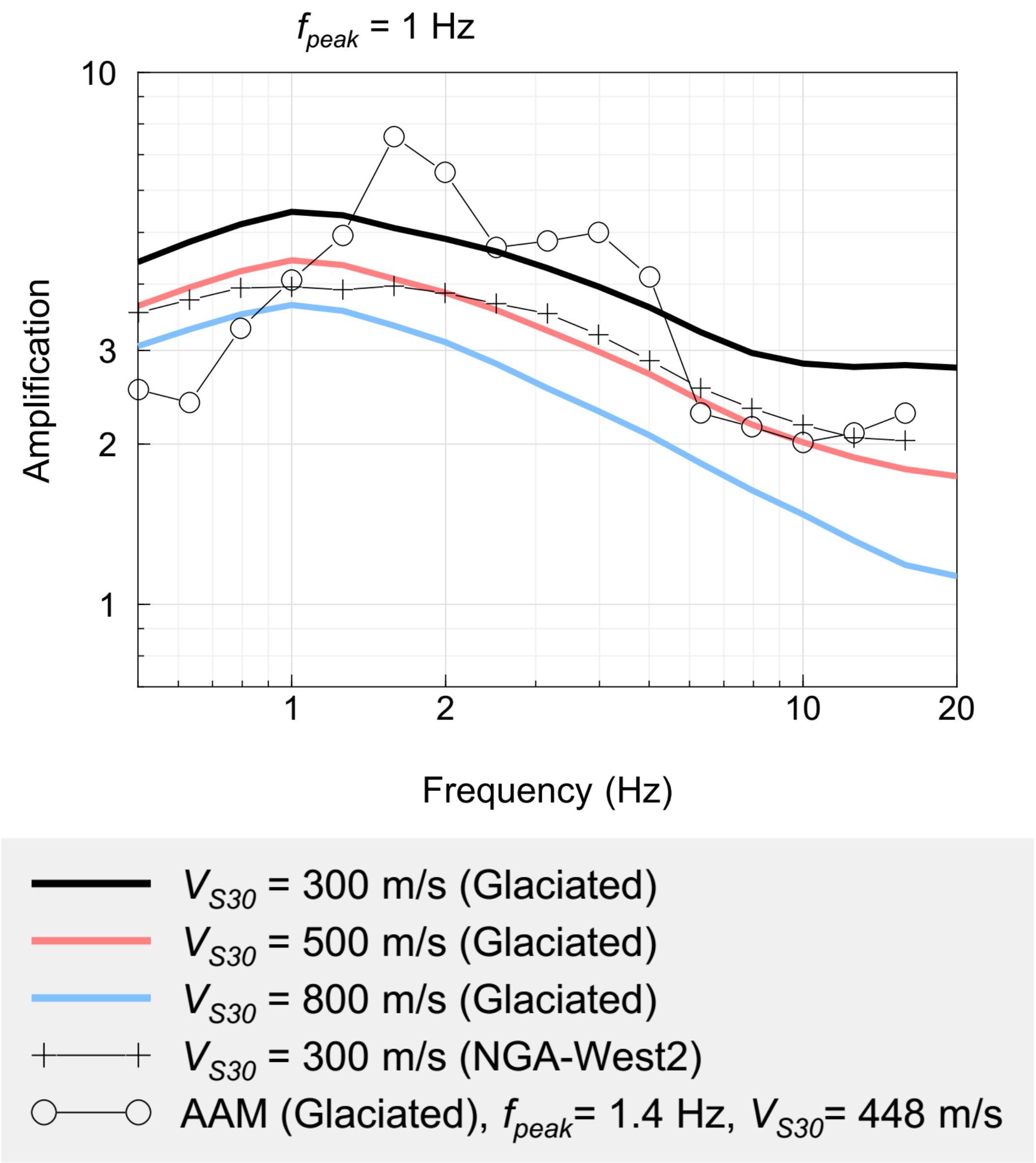
C1, C2 and C3 are coefficients from Hassani and Atkinson (2016) obtained for hard-rock reference site condition.

$$F_S(f, V_{S30}) = \begin{cases} C_4 \log\left(\dfrac{250}{1500}\right) + C_5 & V_{S30} < 250 \\ C_4 \log\left(\dfrac{V_{S30}}{1500}\right) + C_5 & 250 \leq V_{S30} < 1500\ m/s \\ C_5 & V_{S30} \geq 1500\ m/s \end{cases}$$

We constrain C5 such that $Amp\left(f, f_{peak}, V_{S30}\right)$ for sites with VS30> 1500 m/s and no discernible fpeak value is 0.

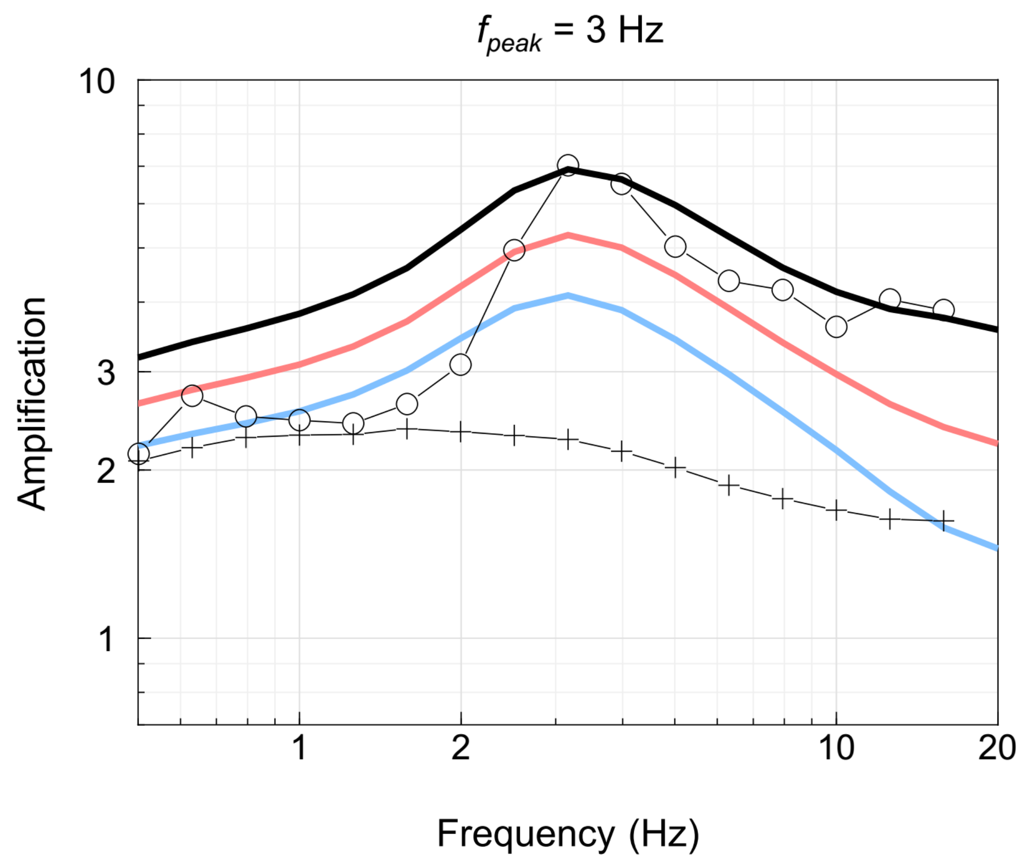
Fpeak and VS30 based amplification model, examples

Glaciated



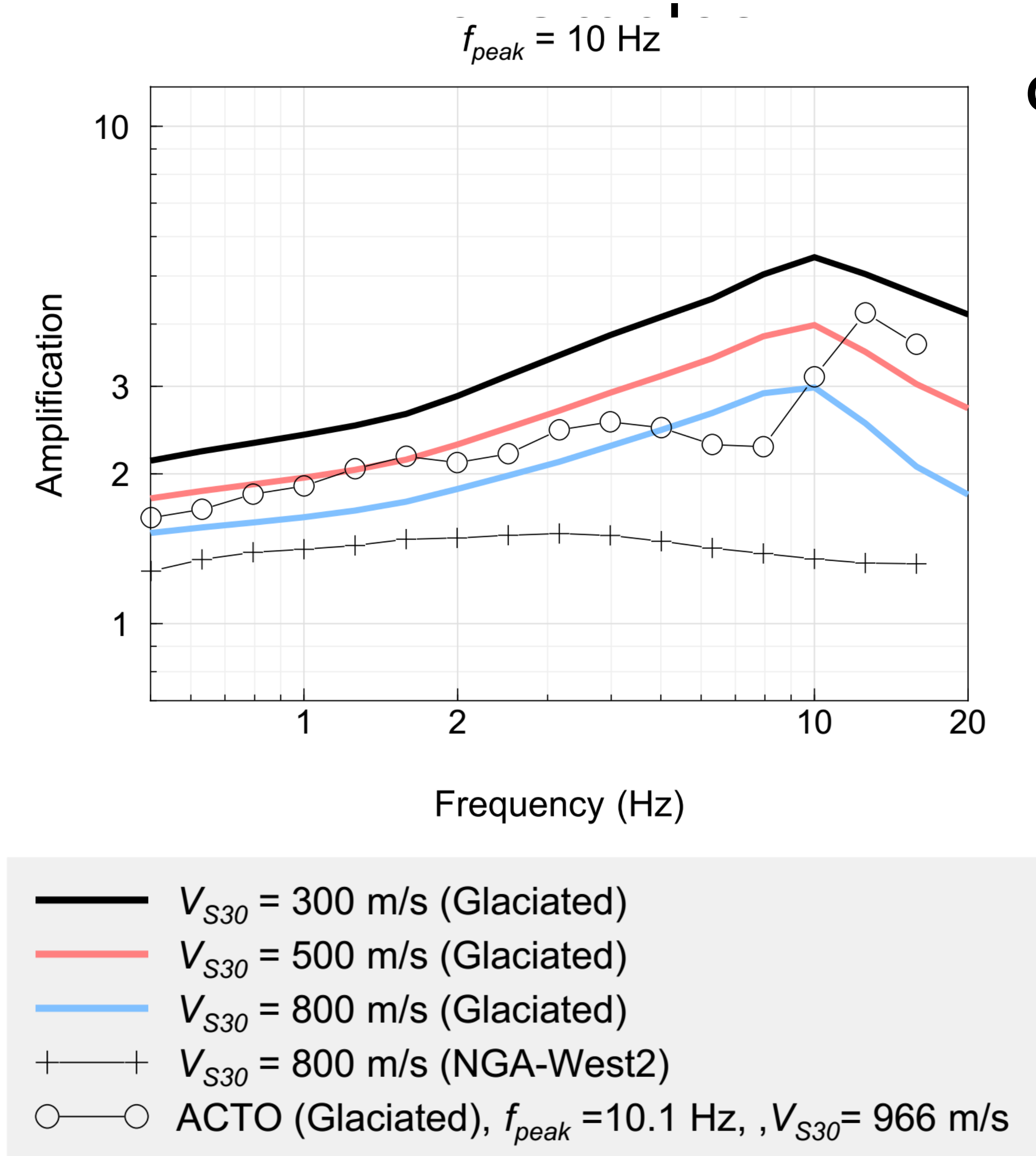
Fpeak and VS30 based amplification model, examples

Glaciated



V_{S30} = 300 m/s (Glaciated)
V_{S30} = 500 m/s (Glaciated)
V_{S30} = 800 m/s (Glaciated)
V_{S30} = 500 m/s (NGA-West2)
ELFO (Glaciated), f_{peak} =2.8 Hz, V_{S30} = 451 m/s

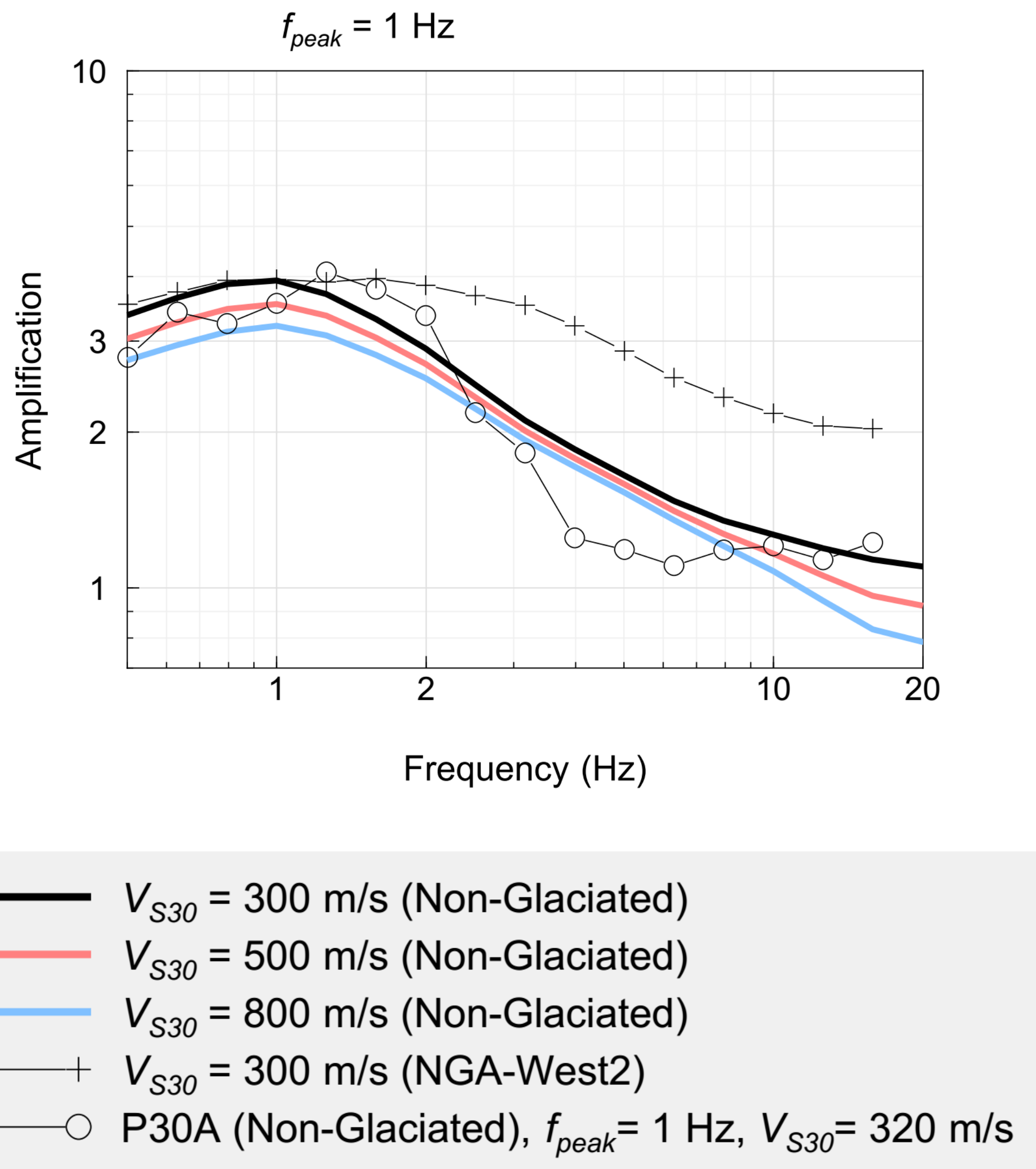
Fpeak and VS30 based amplification model,



Glaciated

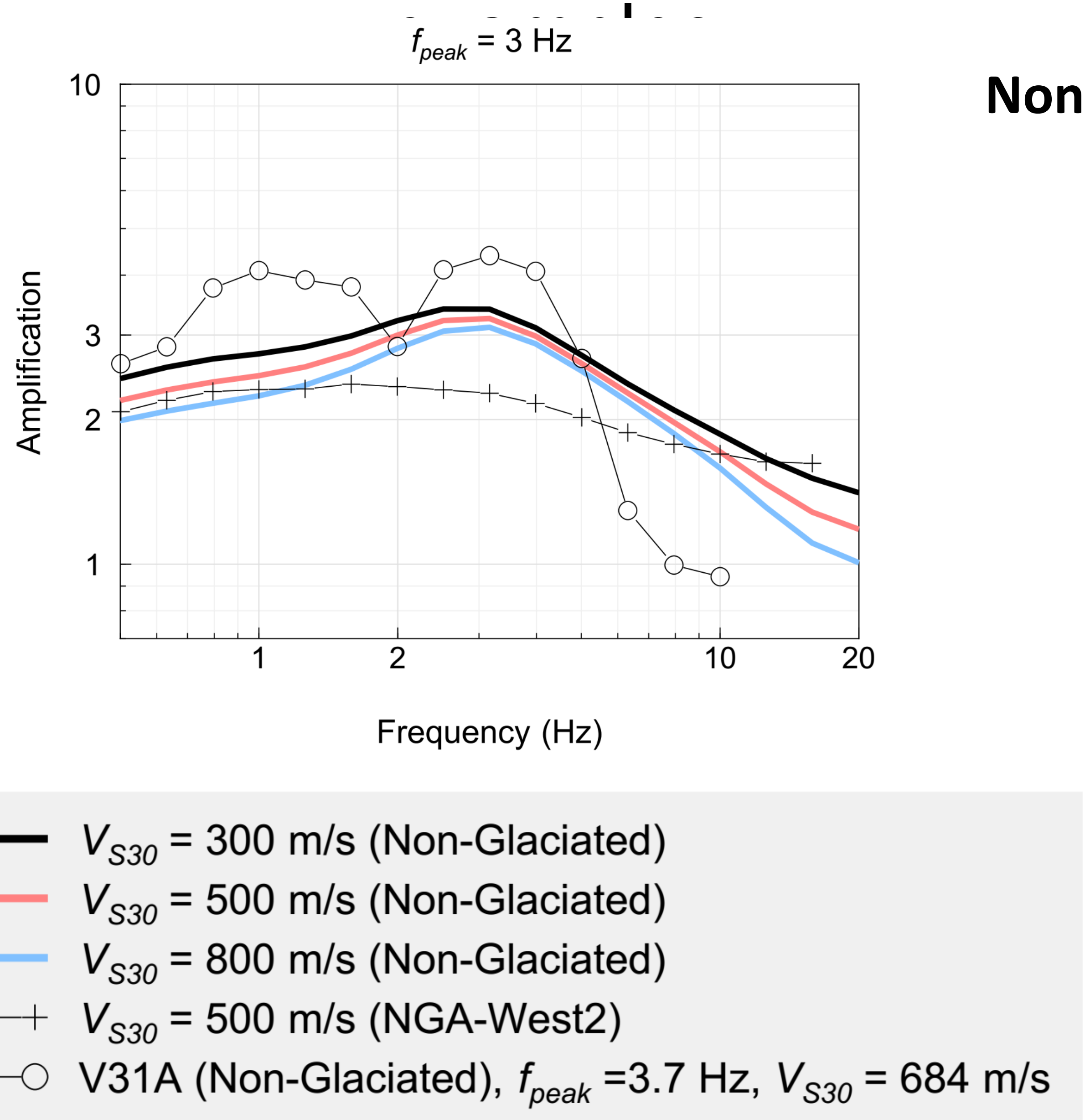
Fpeak and VS30 based amplification model,

Non-Glaciated



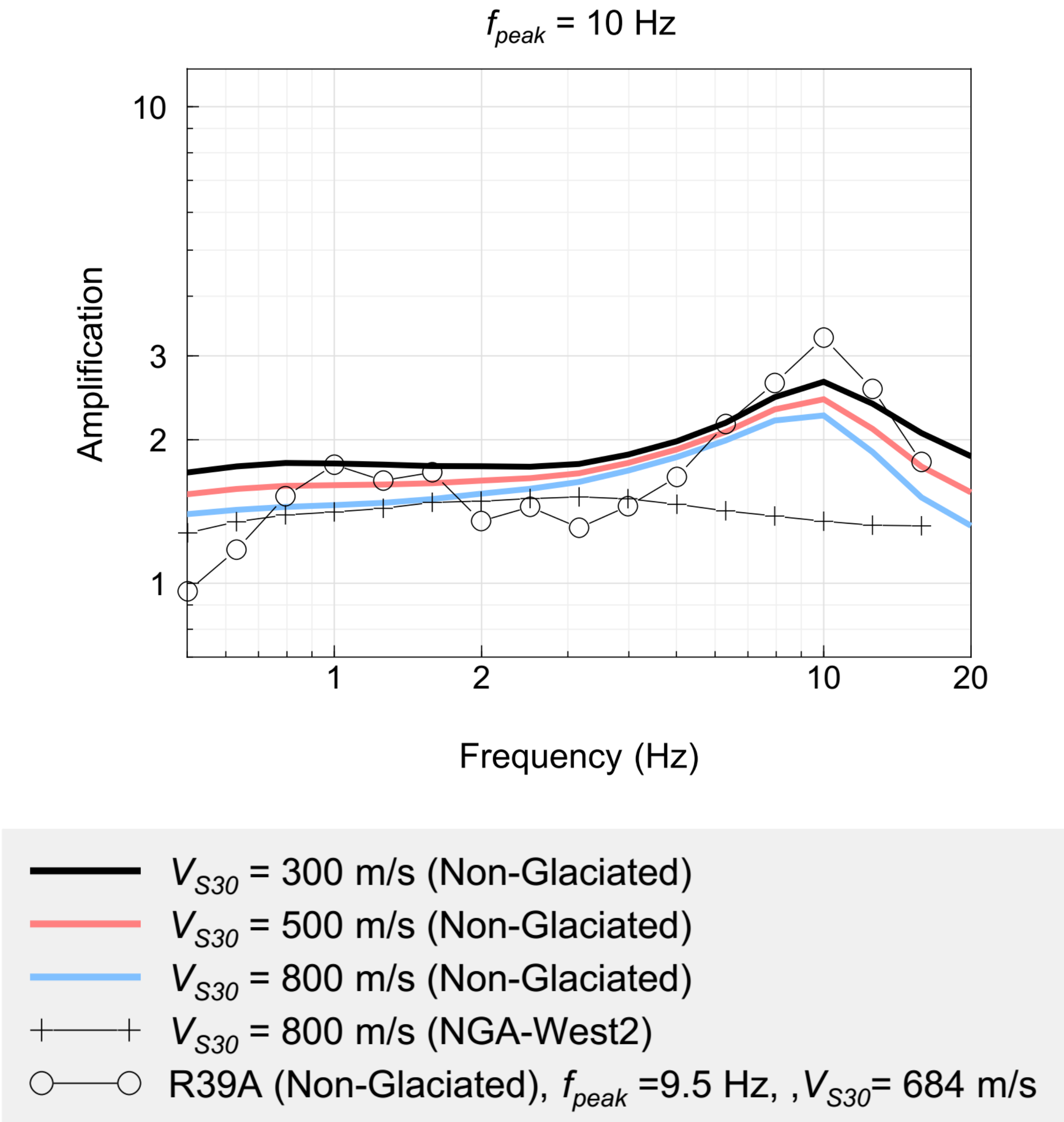
Fpeak and VS30 based amplification model,

Non-Glaciated



Fpeak and VS30 based amplification model, examples

Non-Glaciated



Atkinson's group Recipe for Site Response in CENA

- **If we only have fpeak:**

$$Amp\left(f, f_{peak}, V_{S30}\right) = C_s\left(f, f_{peak}\right)$$

Where the coefficients were derived in Hassani and Atkinson (2016).

- **If we have both fpeak and VS30:**

$$Amp\left(f, f_{peak}, V_{S30}\right) = C_s\left(f, f_{peak}\right) + F_S(f, V_{S30})$$

Where the coefficients of the V30-dependant part of the model were discussed in previous slides.

Atkinson's group Recipe for Site Response in CENA

If we only have VS30:

One alternative is that we use the correlation between VS30 and fpeak to find the fpeak value corresponding to the selected VS30 value (Hassani and Atkinson 2016). Then we use the Hassani and Atkinson (2016) fpeak-based amplification model.