Assessing the Sensitivity of Site Condition Parameters towards seismic local Amplification and their potential Use for Site Response Prediction

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Paolo Bergamo*, Conny Hammer*, Francesco Panzera*, Vincent Perron* & Donat Fäh*

*Swiss Seismological Service (SED), ETH Zürich, Sonneggstrasse 5, CH-8092 Zürich (paolo.bergamo@sed.ethz.ch)

One of the main objectives of the “Site Response” module of the “Risk Model Switzerland” project is the replacement of the current macroseismic amplification map of the Swiss territory (Fäh et al., 2011), with the ambition of producing several frequency-dependent seismic response layers. The strategy devised for this purpose involves the extrapolation of the local amplification experimentally reconstructed at instrumented sites (Edwards et al., 2013), using site condition parameters (SCPs) as support layer for the extrapolation. Therefore, an extensive dataset of site condition information, or proxies, has been compiled for the sites hosting seismic stations of the Swiss network (Bergamo et al., 2018); the dataset comprises parameters from estimated V_S profiles (e.g. V_{S30}), from H/V obtained from noise measurements (e.g. f_0), topographical parameters (e.g. slope, terrain class), geological/geophysical parameters and categorizations. The proxy dataset has been paired with an ensemble of empirical Fourier amplification functions (one from each station), sampled at ten frequencies (0.5-20 Hz). For data completion and comparison, the Swiss database of SCPs and amplification functions has been accompanied by an analogous dataset referring to Japanese Kik-net stations (Aoi et al. 2004). In this work, we have investigated the relation between site condition information and amplification functions using two parallel approaches:

- In the first method, we use statistical tools to evaluate the sensitivity of the various proxies towards the corresponding amplification factors at each frequency. For continuous-variable proxies (e.g. V_{S30}), we used univariate linear regressions (Figure 1a). As for discrete, classification proxies (e.g. the geological categorization), we evaluated their capability to subdivide the total population of stations into subgroups having significantly different behaviors (Welch 1947, Figure1b). The systematic application of these tools enabled us to rank the various proxies in terms of strength of their correlation with amplification, at each frequency. Besides, we assessed whether the same SCPs behave in a similar way at the Swiss and Japanese sites.
- As for the second method, we used a neural network (NN) approach (Bishop 1995) to attempt the prediction of local amplification from proxies. The Japanese and Swiss databases were subdivided into a training and a validation subset, so to first calibrate a NN structure and then evaluate its performance in predicting site response (Figure 1c). With the NN we tested the performance of various typologies and combinations of SCPs.

We highlight the complementarity of the two methods; the first statistical approach provided a list of the most “promising” proxies for amplification prediction with the NN, as well as the proxies exhibiting similar behavior at Swiss and Japanese sites (so that the two datasets could be combined, hence improving the robustness of the neural network structure).

The main outcomes from the two approaches are the following: i) as expected, "direct" proxies (from V_S profiles, H/V measurements) perform generally better than "indirect" proxies (from geology, topography). The first group shows stronger correlation with amplification in the intermediate (1-6.7 Hz) frequency band, the latter at lower frequencies (< 3.3 Hz); ii) more complete, frequency-dependent parameters (e.g. quarter-wavelength velocity, Poggi et al. 2012) are more effective than single-value proxies (e.g. V_{S30}); iii) in general, "direct" proxies are related to amplification in a similar way in Switzerland and Japan (see Figure 1a); "indirect" proxies exhibit different behaviors; iv) the use of NN for the prediction of amplification from "direct" proxies, although achieving discrete results, has highlighted the need to employ a larger training dataset (more than the 350 sites available). This issue is less severe for "indirect" proxies, which cover a larger number of stations.

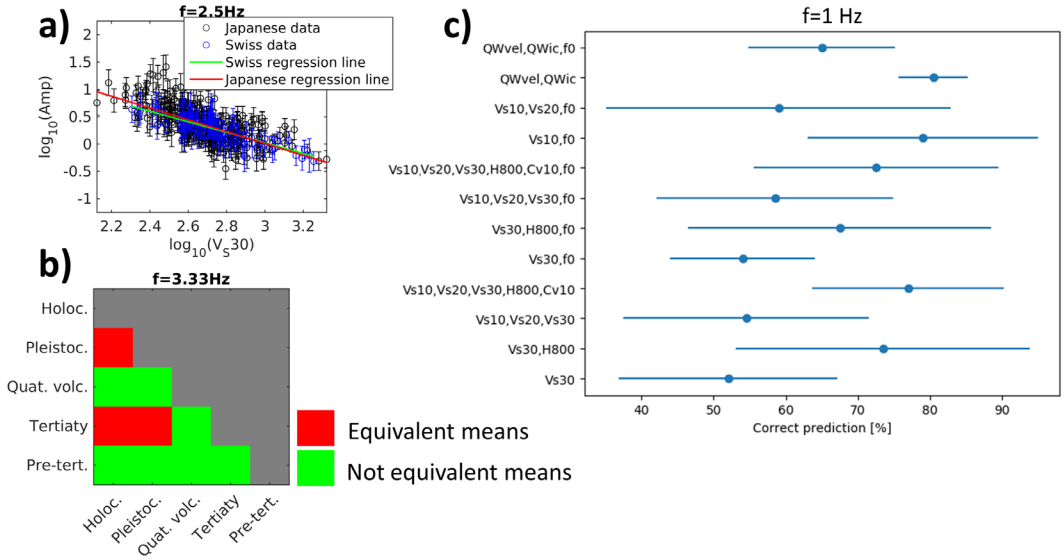

Figure 1 a) Example of linear regression of amplification factors at 2.5 Hz *vs* V_{S30}, Swiss and Japanese data. The scaling of amplification with the proxy is statistically equivalent at Swiss and Japanese sites. b) Japanese data: collation of mean amplification factors (at 3.33 Hz) between pairs of stations' subgroups defined by the geological age categorization. c) Swiss and Japanese data: predictive performance of NN at 1.0 Hz for different groups of direct proxies.

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