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From linear to non-linear site transfer functions: a statistical comparison between instrumental data and 1D numerical simulation results

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The non-linear behavior in soft to moderately stiff soils modifies the linear response by shifting the resonance frequencies towards lower values because of the shear modulus decrease, and reducing the high-frequency motion. The resulting “modulation” of the site response may be quantified by the nonlinear to linear site response ratio, RSRNL-L, comparing the Fourier transfer function for strong events and for weak events. As shown by Régnier et al., 2016 who performed such an analysis for 174 sites of the Japanese KiK-net network, and 3 thresholds of surface PGA [100, 200 and 300 cm/s2], this ratio exhibits a "typical shape"; with a low frequency part above 1 and a high frequency part generally below 1, separated by a transition zone around a site-dependent frequency labelled fNL (characterized by RSRNL-L = 1). The present work intends to compare these observations with the results of extensive non-linear numerical simulation, using about 820 different shear wave velocity profiles from real sites, and non-linear characteristics adapted from the EPRI and Imperial valley models for cohesionless and cohesive soils, respectively. The response of each soil column to about 60 realistic input motion with pga in the range from 0.01 to 4 m/s2, using the NOAH code developed by F. Bonilla. The analysis was performed in the same way as in Régnier et al., 2016, using different PGA ranges : [1, 2 m/s2], [2, 3 m/s2], [3, 4 m/s2], [4, 5 m/s2], and [5, 6 m/s2]. Non-linear soil behaviour results in significant site response modifications even for moderate PGA values of 100 cm/s2, in that case mainly for soft soils with low VS30 value. The resulting RSRNL-L functions exhibit a qualitatively similar shape compared to instrumental data. fNL values are linked to the selected NL models, and exhibit a satisfactory correlation with site classifications based on either VS30 or f0: the lower VS30 or f0, the lower fNL. The amount of low-frequency amplification (i.e. for f < fNL) increases with increasing non-linearity, i.e. with increasing pga and/or strain, and the same for the high-frequency (i.e. f > fNL) de-amplification. The final aim is to propose a model of frequency-dependent “NL modulation” to be applied to measured or computed linear transfer functions, as a function of pga level and site characteristics, including VS10, VS30 and/or f0.