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Outstanding Student Poster & PICO Contest

Ambivalent Amplifications

Using horizontal-to-vertical spectral ratios to characterise subsurface seismic properties

Janneke van Ginkel[1,2], Elmer Ruigrok[2] and Rien Herber[1]

[1] Energy and Sustainability Research Institute, University of Groningen
[2] Seismology and Acoustics, Royal Netherlands Meteorological Institute

Contact: j.a.van.ginkel@rug.nl

university of groningen

Royal Netherlands Meteorological Institute

Introduction

Soft sediment covers **amplify earthquake waves** and subsequently increase the degree of damage on buildings. To measure local site resonance we use the KNMI seismometer network (Fig. 2) across the **Groningen field, the Netherlands**, which is continuously measuring **ambient noise, teleseismic phases and local events**. This provides a large dataset to derive seismic properties for the shallow subsurface, which are important for seismic hazard analysis.

We compute **Horizontal-to-Vertical Spectral Ratios** (HVSR) from the ambient noise and teleseismic phases and calculated shear wave velocities for the complete sedimentary cover.
Furthermore, a **shallow impedance contrasts** (Fig. 1) is studied in detail to get a feeling for **amplitude variability** per site. **Amplification factors** from local seismic events are compared with the noise HVSR relative amplitudes.

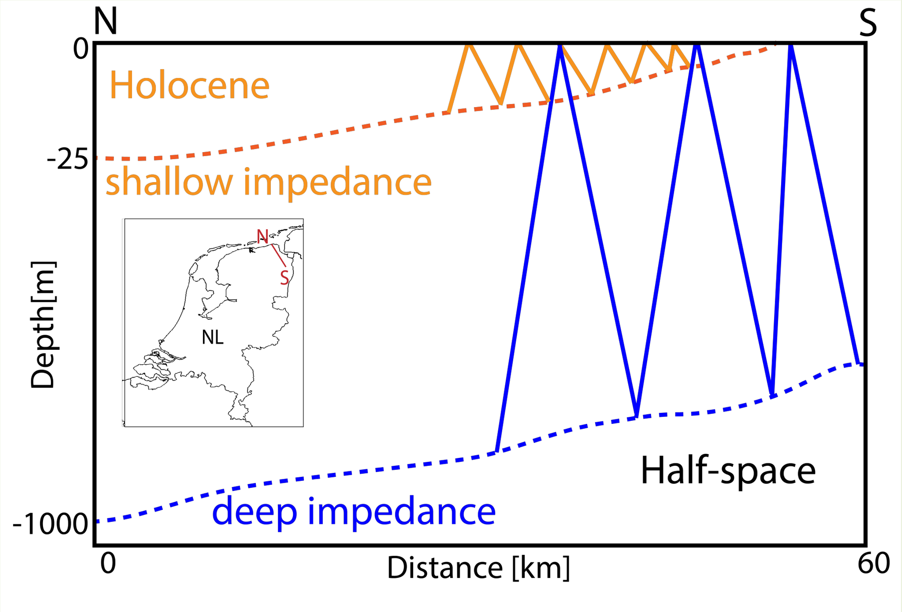


Figure 1 Schematic cross-section of the sediment cover in Groningen. Waves resonate between a deep -and shallow impedance contrast and the surface.

Issues arise…

Constraints on local site amplification are generally established by using a **hard rock reference site.** In the Netherlands, this reference site is **absent**. Therefore we discuss alternative methods to model variability in amplitudes.

The Network

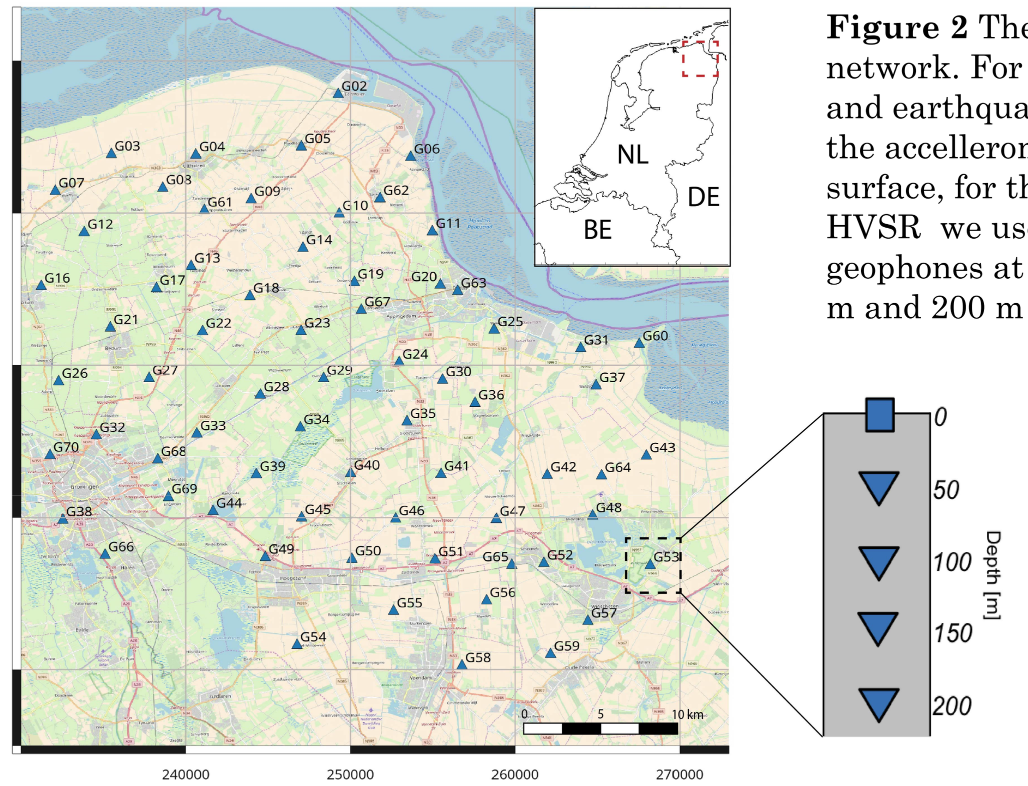


Figure 2 The Groningen network. For the noise HVSR and earthquake amplitudes , the accellerometer at the surface, for the teleseismic HVSR we use the 4.5Hz geophones at 50 m, 100 m, 150 m and 200 m depth.

Method for estimating S wave velocities

Step 1: HVSR from teleseismic phases

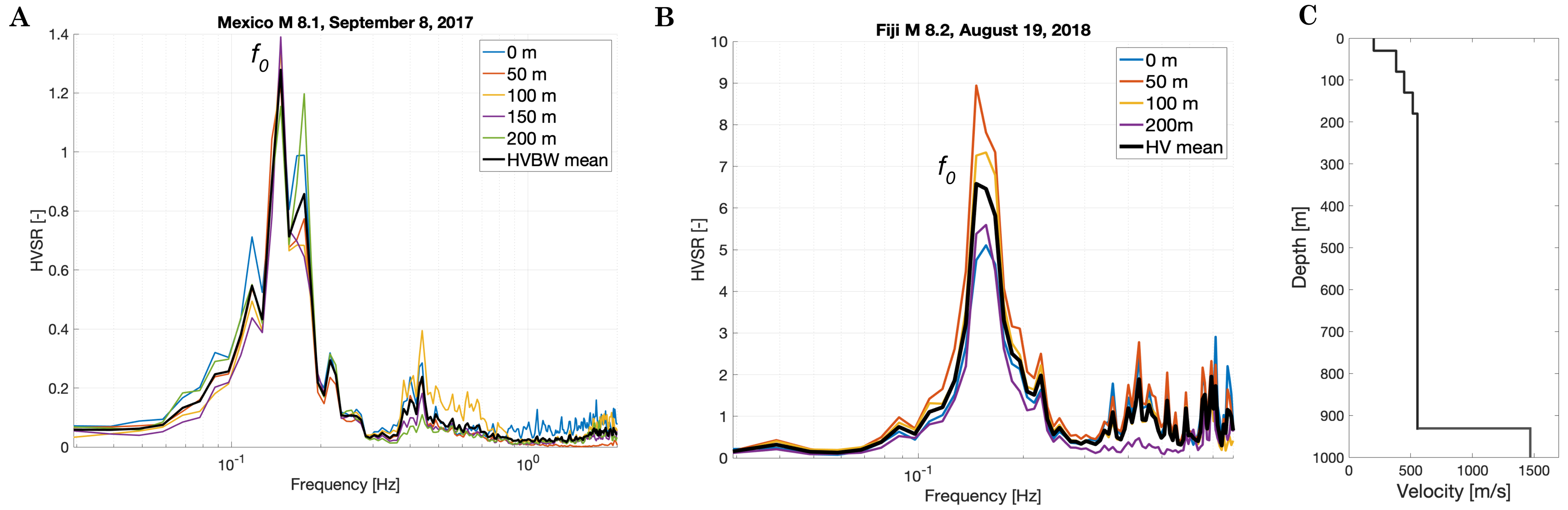


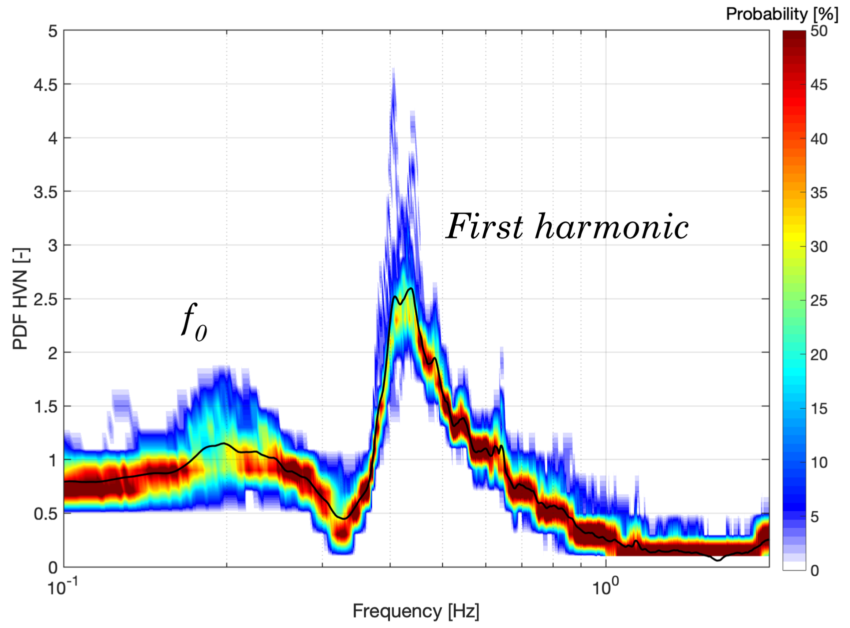
Figure 3 Examples of HVSR curves for one borehole from teleseismic phases. f_0 represents the fundamental resonance peak. **A)** S arrivals from a Mexico earthquake. **B)** PKP arrivals from a Fiji earthquake. **C)** Example of a shear wave velocity profile for the complete sedimentary cover (down to deep impedance). The upper detailed 200 m is derived from Hofman et al. (2017), the lower ~600m velocity profile is constructed with the HVSR from 5 teleseismic events.

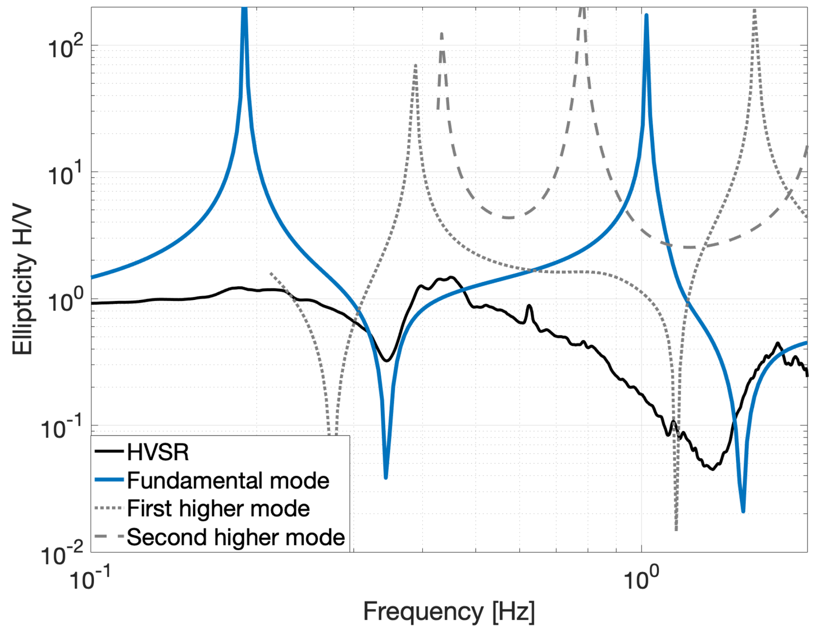
Step 2: Calculate S wave velocities from multiple teleseismic arrivals for al boreholes

$$f_0 = \frac{Vs}{4 * h}$$

Step 3: Probability density functions from noise HVSR

Figure 4 Probability density function of the HVSR from the ambient noise where one month of data is sufficient to find a stable curve. The peak at 0.42 Hz is considered at the first harmonic. The fundamental resonance peak (f_0) is not well expressed due to instrument noise.





Step 4: Ellipticity forward modelling with estimated S wave velocities as major input

Figure 5 Example of modelled Rayleigh ellipticity. These models are based on the S wave velocity profiles calculated in step 2. The good fit between the trough of the fundamental mode from noise HVSR, with the modeled Rayleigh ellipticity notch, prove the robustness of the velocity estimation for a multilayer over half-space.

? How can we use ambient noise as predictive amplification tool?

Earthquakes

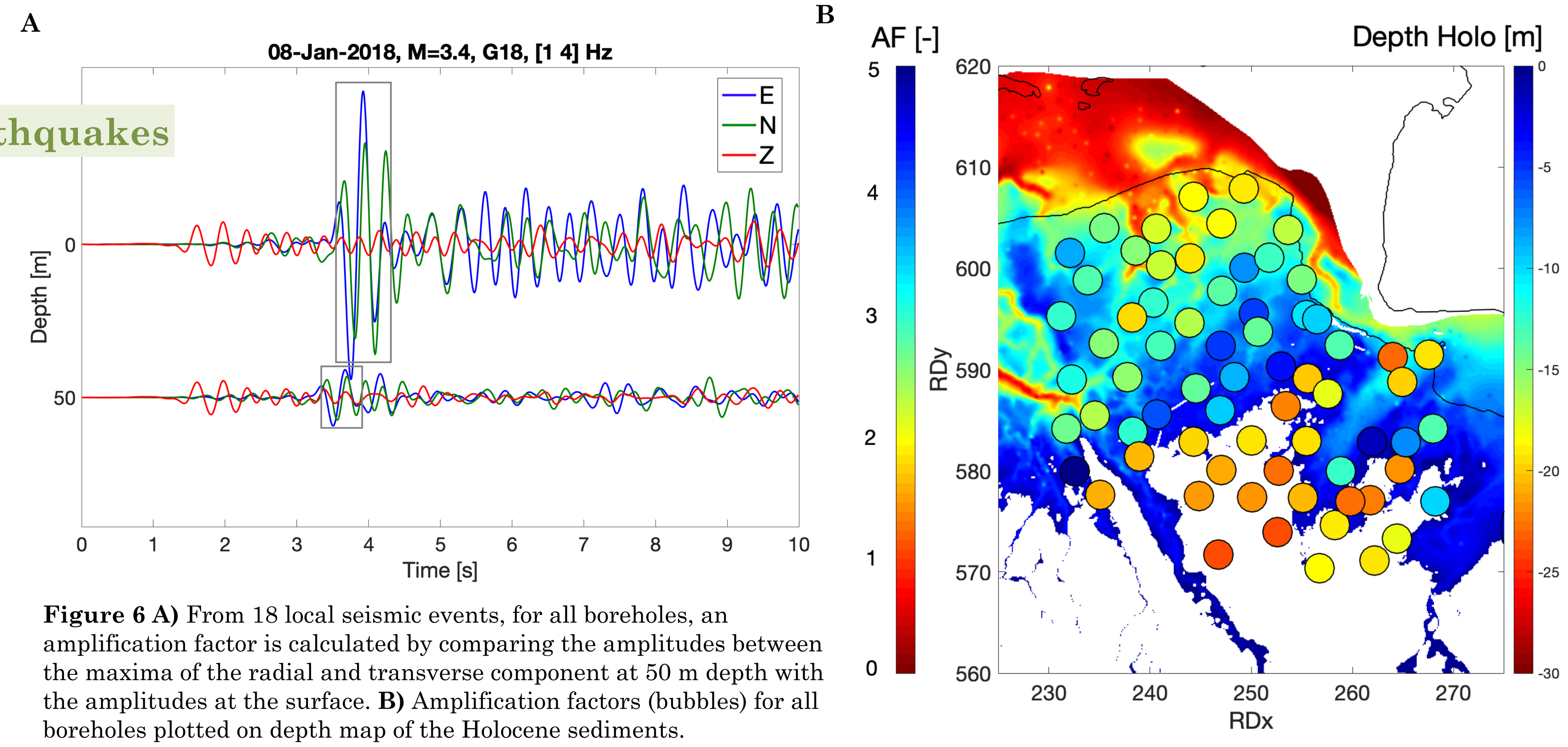


Figure 6 A) From 18 local seismic events, for all boreholes, an amplification factor is calculated by comparing the amplitudes between the maxima of the radial and transverse component at 50 m depth with the amplitudes at the surface. **B)** Amplification factors (bubbles) for all boreholes plotted on depth map of the Holocene sediments.

Ambient noise

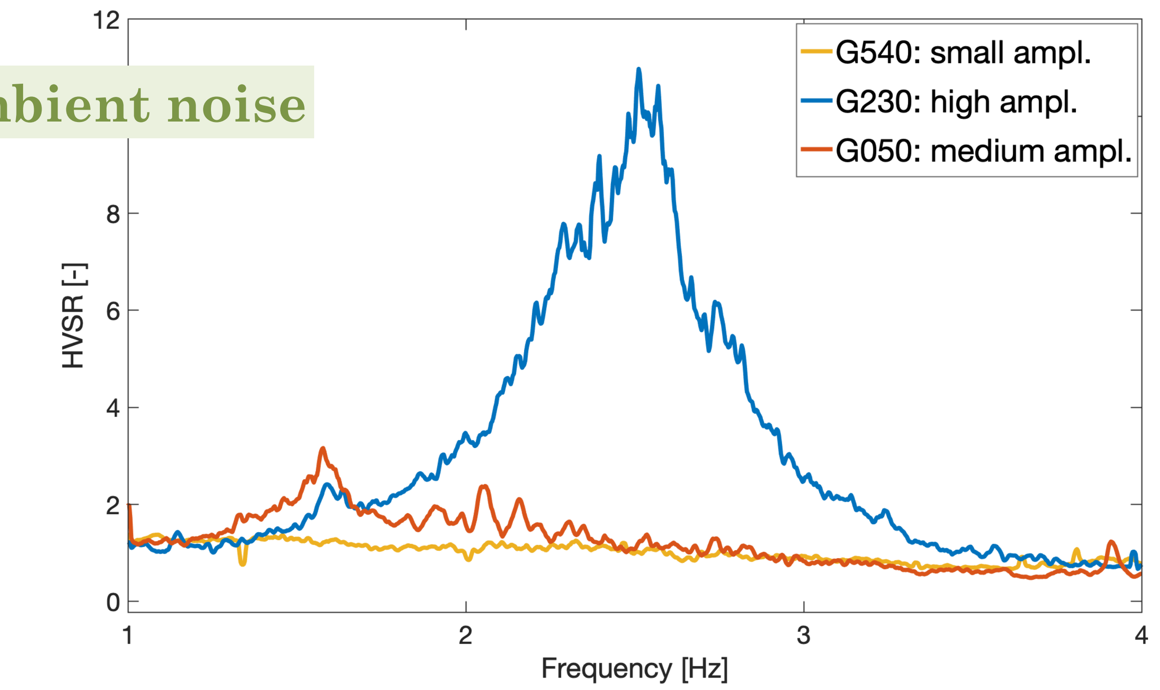


Figure 7 HVSR of the ambient noise for frequency range 1-4 Hz can be categorised into 3 regimes: 1. High HVSR amplitudes (>5). 2. Medium amplitudes (>2) and 3. Small amplitudes (<2).

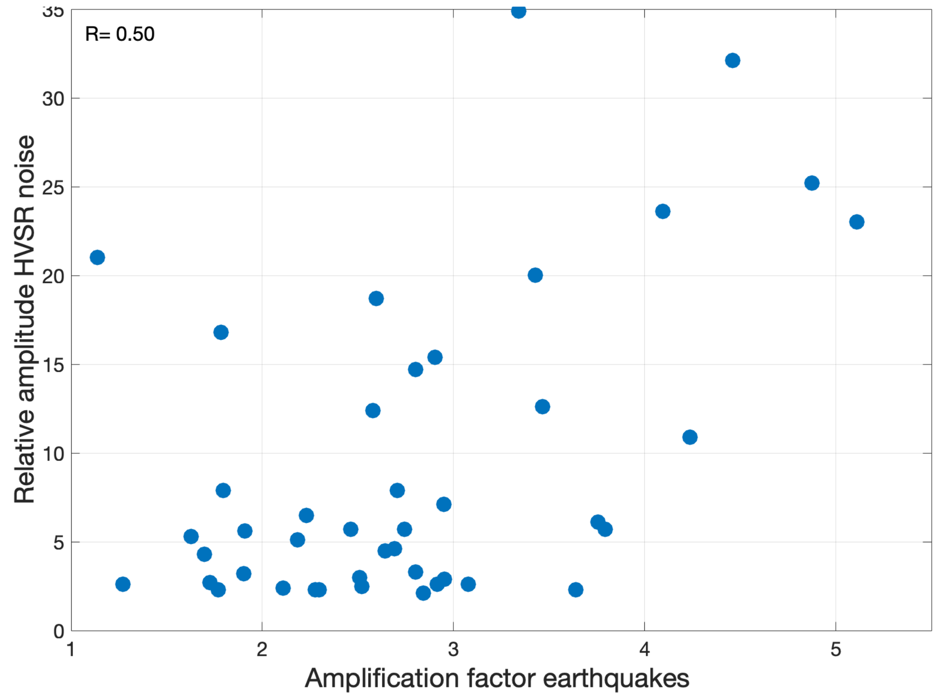


Figure 8 Correlation between the amplification factor (Fig. 6) and relative amplitudes of the noise HVSR (Fig. 7) from all boreholes.

Discussion on amplification

- Most Dutch buildings resonate at frequencies from 1-4 Hz, for this frequency band the f_0 from noise HVSR shows a clear lateral variability which is related to the shallow impedance contrast at base Holocene sediments.
- For all boreholes. amplification factors of 18 events are calculated and show a weak correlation with the relative amplitudes of the noise HVSR.
- What would be a better method to compare the HVSR from ambient noise with S wave amplification?
- Next step will be calculating HVSR from earthquakes and compare those with HVSR of the ambient noise.