Geophysical Research Abstracts
Vol. 21, EGU2019-4344-1, 2019
EGU General Assembly 2019

Using Horizontal to Vertical Spectral Ratio’s to characterize subsurface seismic properties in Groningen, the Netherlands

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Site characterization is key for seismic hazard analysis and risk mitigation but to obtain the subsurface properties is often a challenge. Over the last decades, increasing numbers of induced seismic events caused by gas production triggered the research on seismicity and site response in Groningen, the Netherlands. Waves are amplified within an approximately 800 m thick blanket of unconsolidated sediments at the surface. We have used both the ambient field and teleseismic arrivals to determine shear velocity profiles for this top soft sedimentary layer.

Local shear wave velocity profiles are retrieved from H/V ratios of strong teleseismic events at 70 stations, each equipped with 1 accelerometer at the surface and 4 geophones at 50m depth intervals down to 200m. Using an existing shear velocity model for the top 200 meters, the body-wave H/V ratios are used to invert for the lower 600 meters of the soft sediments. Two borehole log datasets are used for calibration. From ambient noise data, we compute the probability density functions of the H/V ratios. Doing this for one month of data, results in stable mean H/V ratios. Based on the body- and surface wave forward modeling we find that the ambient field between 0.1 and 0.25 Hz is dominated by body waves, while at frequencies between 0.25 and 1.0 Hz, the higher mode Rayleigh waves are dominant. With this interpretation, a close relationship is observed between the H/V spectral ratios from the ambient field, S-wave resonance frequencies and the ellipticities of the Rayleigh waves. Furthermore, the good consistency between the earthquake and noise based models do confirm the robustness of the derived shear wave velocity profiles.

The power of this study is the combination of body-and surface wave H/V ratios retrieved from multiple H/V approaches and the possibility to quality check the velocity profiles. These methods allow evaluation of the ambient seismic field. Furthermore, additional shallow impedance contrasts are determined. Such contrasts can cause additional wave amplification, which is important to take into account in site response modeling.