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Deep Geothermal Energy Production: case study of the impact of induced seismicity using probabilistic methods in combination with microtremor measurement for site effect estimation

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In a first approach, we modified the well-established PSHA (probabilistic seismic hazard analysis) method for natural seismicity for the case of anthropogenic induced seismicity occurring during the operation phase of a geothermal power plant. For the model used, we made simplifying approximations and assumptions regarding ground motion attenuation and seismicity rate. This allows estimating the seismic hazard originating from the geothermal energy production as the probability of exceedance of ground motion of stipulated limiting values. This has the advantage that engineer standards specified in the procedures for natural seismicity (e.g. impact on buildings and people, see German industry standard DIN 4150, 4149) can also be used to estimate the seismic hazard in the context of induced seismicity. Thus, it becomes possible e.g. for the regulator responsible for commissioning of a geothermal plant to determine whether the number of exceedances at these given limits of ground motion (e. g. the limiting standard value of ground motion for perceptibility of vibrations) are acceptable at a site or not. Additionally, hazard curves of induced and natural seismicity can be compared to study their different impacts. The current work aims at refining our PSHA model by incorporating effects of local site conditions. They will be quantified using a concept of ambient seismic noise array and H/V measurements in combination with active seismic and geological data. The applied methods comprise frequency–wavenumber (f–k) and spatial autocorrelation (SPAC) analysis, multichannel analysis of surface waves (MASW) and ellipticity curve analysis for Rayleigh waves ('RayDec' method). The basis for the estimation of the desired site effects is the determination of the shear wave velocity for depths down to the bedrock (or first strong impedance contrast). We use several small aperture arrays in linear and 2D circular configuration to derive the dispersion curve of seismic surface waves as composite branches from controlled and ambient noise sources. This procedure helps with the identification of unwanted mode mixing and, hence, avoids misinterpretation of dispersion curves prior to inversion. Incorporation of available geological information proved useful to clear ambiguities within the inversion process. Results from sites in the upper Rhine Graben and the Bavarian Molasses will be presented.