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Epistemic Uncertainty and Limitations of the Kappa0 model for Near-surface Attenuation at Hard Rock Sites

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The determination of near-surface attenuation for hard rock sites is an important issue in a wide range of seismological applications, particularly seismic hazard analysis. In this article we choose six hard to very-hard rock sites (Vs30 1030 to 3000 m/s) and apply a range of analysis methods to measure the observed attenuation at distance based on a simple exponential decay model with whole-path attenuation operator κ. The κ values are subsequently decoupled from path attenuation (Q) so as to obtain estimates of near-surface attenuation ($\kappa 0$). Five methods are employed to measure κ which can be split into two groups: broadband methods and high-frequency methods. Each of the applied methods has advantages and disadvantages, which are explored and discussed through the comparison of results from common datasets.
In our first step we examine the variability of the individual measured κ values. Some variation between methods is expected due to simplifications of source, path, and site effects. However, we find that significant differences arise between attenuation measured on individual recordings, depending on the method employed or the modelling decisions made during a particular approach. Some of the differences can be explained through site amplification effects: although usually weak at rock sites, amplification may still lead to bias of the measured κ due to the chosen fitting frequency bandwidth, which often varies between methods. At some sites the observed high-frequency spectral shape was clearly different to the typical κ attenuation model, with curved or bi-linear rather than linear decay at high frequencies. In addition to amplification effects this could be related to frequency-dependent attenuation effects (e.g., Q(f)): since the κ model is implicitly frequency independent, κ will in this case be dependent on the selected analysis bandwidth.
In our second step, using the whole-path κ datasets from the five approaches, we investigate the robustness of the near-surface attenuation parameter $\kappa 0$ and the influence of constraints, such as assuming a value for the regional crustal attenuation (Q). We do this by using a variety of fitting methods: least-squares, absolute amplitude, and regressions with and without fixing Q to an a priori value. We find that the value to which we fix Q strongly influences the near-surface attenuation term $\kappa 0$. Differences in Q derived from the data at the six sites under investigation could not be reconciled with the average values found previously over the wider Swiss region. This led to starkly different $\kappa 0$ values, depending on whether we allowed for a data-driven Q, or whether we forced Q to be consistent with existing simulation models or GMPEs valid for the wider region. Considering all the possible approaches we found that the contribution to epistemic uncertainty for $\kappa 0$ determination at the six hard-rock sites in Switzerland could be represented by a normal distribution with standard deviation $\sigma\kappa 0$=0.0083$\pm$0.0014 s.