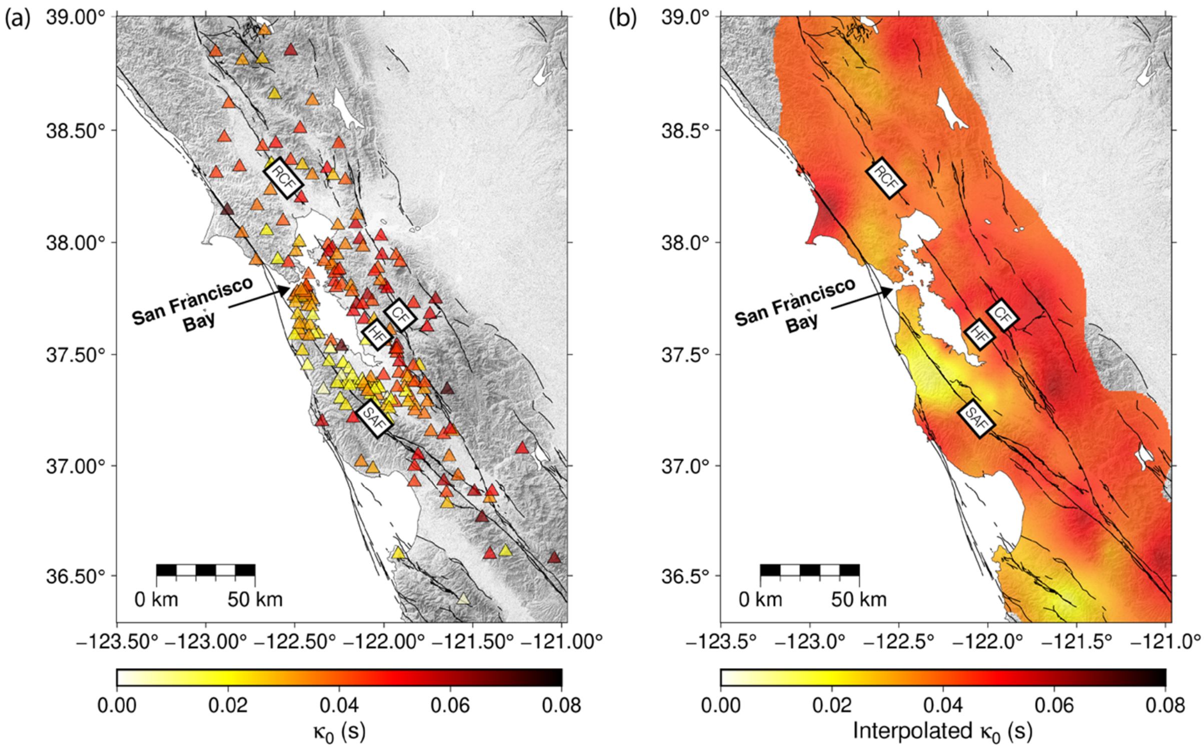
Estimates of κ_0 in the San Francisco Bay Area: Complexities of isolating amplification and attenuation at non-rock sites

Tara Nye[1,2], Valerie J. Sahakian[1], Elias King[1,3], Annemarie Baltay[2], and Alexis Klimasewski[1,4]
[1]Department of Earth Sciences, University of Oregon, Eugene, Oregon, USA
[2]U.S. Geological Survey, Earthquake Science Center, Moffett Field, California, USA
[3]now at Nanohmics, Austin, Texas, USA
[4]now at Agrograph, Madison, Wisconsin, USA
tnye@usgs.gov

Ground-motion studies are a key component of seismic hazard analyses and often rely on information characterizing the earthquake source, path, and site. Site-specific studies are of particular interest for earthquake engineers, as near-site conditions can have a significant impact on the frequency content of ground motion and building response during an earthquake. Most ground-motion models (GMMs) account for varying site effects by including a site term conditioned on the time-averaged shear wave (V_S) velocity in the upper 30 meters (V_{S30}), and sometimes the depth to the 1 km/s V_S isosurface ($Z_{1.0}$; representative of basin depth). However, these parameters do not fully capture site effects because they are depth-limited and primarily account for site amplification. Kappa (κ) is a parameter that describes the high-frequency attenuation of spectra resulting from both path and site effects. Inclusion of the site-contribution to κ (κ_0) into ground-motion studies could be beneficial; however, unlike V_{S30} which can be obtained by proxy, κ_0 is generally measured on observational data. In this study, we develop a regional κ_0 model for the complex San Francisco Bay area (SFBA) to contribute to ground-motion studies in this seismically-active region.

Our dataset consists of ~11,000 three-component earthquake acceleration recordings from 227 **M**3.5–5.5 events at 228 stations in the SFBA. We invert for κ on the *S*-wave portion of the individual acceleration spectra by fitting a linear slope to the high-frequency decay. Most κ studies have been conducted on harder rock sites to avoid site amplification effects. However, softer sites are arguably more critical for seismic hazard applications. The SFBA is covered by considerable weak material in the shallow subsurface, which makes it both geologically complex and critical to accurately model for improved hazard estimates. To minimize effects of site amplification in solving for κ in this region, we compute the average earthquake-based horizontal-to-vertical spectral ratio (eHVSR) at each site and select the frequencies that bound a generally flat portion of the curve. These frequency bounds serve as the maximum limits to the frequency range used for the κ inversion. To isolate the site component (κ_0), we perform a linear regression on the epicentral distance versus κ at each site, and the y-intercept is assumed to be κ_0.

We find κ_0 to vary substantially in the SFBA with estimates ranging from 0.003 s on the west side of the bay to 0.072 s on the east side (Figure 1a). The spatial distribution of κ_0 correlates with patterns in surficial geology. Higher κ_0 (i.e., greater attenuation) is observed in regions characterized by basins, alluvium, bay mud, and other weak material, as well as regions dominated by younger faults. Conversely, the segment of the older San Andreas Fault cutting through the Santa Cruz mountains is the main feature where lower κ_0 (i.e., less attenuation) is observed. The western peninsula also lacks much surficial sediment and is characterized by uplifted consolidated rocks. We correlate κ_0 estimates with GMM site residuals for peak ground acceleration, peak ground velocity, and pseudospectral acceleration at various periods to evaluate its robustness as a site-predictor of ground motion. κ_0 exhibits correlations with higher-frequency intensity measures and could prove informative if included in regional ground-motion studies. To support the addition of κ_0 to SFBA seismic hazard studies, we produce a continuous model of κ_0 by kriging the



station-specific estimates (Figure 1b).

Figure 1. (a) Station-based κ_0 estimates and (b) kriged κ_0 map. Several prominent faults are labeled: San Andreas Fault (SAF), Hayward Fault (HF), Calaveras Fault (CF), and Rodgers Creek Fault (RCF).

*Some of this work has been previously published (see reference below).

Nye, T. A., Sahakian, V. J., King, E., Baltay, A., and Klimasewski, A. (2022). Estimates of κ_0 and effects on ground motions in the San Francisco Bay Area. *Bulletin of the Seismological Society of America*, *113*(2), 823–842. doi: 10.1785/0120220046