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Do PSHA maps overpredict or are there shaking deficits in the historic record?

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Probabilistic Seismic Hazard Assessment (PSHA) attempts to forecast the fraction of sites on a hazard map where ground shaking will exceed the mapped value within some time period. Because the maps are probabilistic forecasts, they explicitly assume that shaking will exceed the mapped value some of the time. At a point on a PSHA map, the probability p that during t years of observations shaking will exceed the value on a map with a T-year return period is assumed to be described by the exponential cumulative density function: $p = 1 – \exp(-t/T)$. The fraction of sites, f, where observed shaking exceeds the mapped value should behave the same way. To assess the 2018 USGS National Seismic Hazard Model maps for California, we created the California Historical Intensity Mapping Project (CHIMP), a 162-yr long dataset that combines and consistently reinterprets seismic intensity information that has been stored in disparate and sometimes hard-to-access locations (Salditch et al., 2020). We use two performance metrics; M0 based on the fraction of sites where modeled ground motion is exceeded, and M1 based on of the difference between the mapped and observed ground motion at all sites. M0 is implicit in PSHA because it measures the difference between the predicted and observed fraction of site exceedances and is therefore a key indicator of map performance.

We explore these metrics for CHIMP. Assuming the dataset to be correct, it appears that the hazard maps overpredicted shaking even correcting for the time period involved. Assuming the model is also correct, a shaking deficit exists between the model and observations. Possible reasons for this apparent overprediction/shaking deficit include: 1) the observations in CHIMP are biased low; 2) the observation period has been less seismically active than typical – either by chance or temporal variability due to stress shadow effects; 3) the model overpredicts due to either the earthquake rupture forecast or the ground motion models. Similar overpredictions appear for past shaking data in Italy, Japan, and Nepal, implying that seismic hazards are often overestimated. Whether this reflects too-high models and/or biased data remains an important question.