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Near-field spectral analysis of data-integrative dynamic rupture earthquake simulations of the 1992 Landers earthquake

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The rise of observations from Distributed Acoustic Sensing (e.g., Zhan 2020) and high-rate GNSS networks (e.g., Madariaga et al., 2019) highlight the potential of dense ground motion observations in the near-field of large earthquakes. Here, spectral analysis of >100,000 synthetic near-field strong motion waveforms (up to 2 Hz) is presented in terms of directivity, corner frequency, fall-off rate, moment estimates and static displacements.

The waveforms are generated in 3D large-scale dynamic rupture simulations which incorporate the interplay of complex fault geometry, topography, 3D rheology and viscoelastic attenuation (Wollherr et al., 2019). A preferred scenario accounts for off-fault deformation and reproduces a broad range of observations, including final slip distribution, shallow slip deficits, and spontaneous rupture termination and transfers between fault segments. We examine the effects of variations in modeling parameterization within a suite of scenarios including purely elastic setups and models neglecting viscoelastic attenuation.

First, near-field corner frequency mapping implementing a novel spectral seismological misfit criterion reveals rays of elevated corner frequencies radiating from each slipping fault at 45 degree to rupture forward direction. The azimuthal spectral variations are specifically dominant in the vertical components indicating we map rays of direct P-waves prevailing (Hanks, 1980). The spatial variation in corner frequencies carries information on co-seismic fault segmentation, slip distribution, focal mechanisms and stress drop. Second, spectral fall-off rates are variably inferred during picking the associated corner frequencies to identify the crossover from near-field to far-field spectral behaviour in dependence on distance and azimuth. Third, we determine static displacements with the help of near-field seismic spectra.

Our findings highlight the future potential of spectral analysis of spatially dense (low frequency) ground motion observations for inferring earthquake kinematics and understanding earthquake physics directly from near-field data; while synthetic studies are crucial to identify "what to look for" in the vast amount of data generated.

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