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Bayesian Inference of Seismic Sources Using a 3-D Earth Model for the Japanese Islands Region

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Earthquake source inversion is an established problem in seismology. Nevertheless, one-dimensional Earth models are commonly used to compute synthetic data in point- as well as finite-fault inversions. Reliance on simplified Earth models limits the exploitable information to longer periods and as such, contributes to notorious non-uniqueness of finite-fault models. Failure to properly account for Earth structure means that inaccuracies in the Earth model can map into and pollute the earthquake source solutions.

To tackle these problems we construct a full-waveform 3-D Earth model for the Japanese Islands region and infer earthquake source parameters in a probabilistic way using numerically computed 3-D Green's functions.

Our model explains data from the earthquakes not used in the inversion significantly better than the initial model in the period range of 20-80 s. This indicates that the model is not over-fit and may thus be used for improved earthquake source inversion.

To solve the forward problem, we pre-compute and store Green's functions with the spectral element solver SES3D for all potential source-receiver pairs. The exploitation of the Green's function database means that the forward problem of obtaining displacements is merely a linear combination of strain Green's tensor scaled by the moment tensor elements.

We invert for ten model parameters – six moment tensors elements, three location parameters, and the time of the event. A feasible number of model parameters and the fast forward problem allow us to infer the unknowns using the Bayesian Markov chain Monte Carlo, which results in the marginal posterior distributions for every model parameter. The Monte Carlo algorithm is validated against analytical solutions for the linear test case. We perform the inversions using real data in the Japanese Islands region and assess the quality of the solutions by comparing the obtained results with those from the existing 1-D catalogues.