Seismic source inversion using Hamiltonian Monte Carlo and a 3-D Earth model in the Japanese Islands

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We present a proof-of-concept catalogue of full-waveform seismic source solutions for the Japanese Islands area. Our method is based on the Bayesian inference of source parameters and a tomographically derived heterogeneous Earth model, used to compute Green's strain tensors. We infer the full moment tensor, location and centroid time of the seismic events in the study area.

To compute spatial derivatives of Green's functions, we use a previously derived regional Earth model (Simutė et al., 2016). The model is radially anisotropic, visco-elastic, and fully heterogeneous. It was constructed using full waveforms in the period band of 15–80 s.

Green's strains are computed numerically with the spectral-element solver SES3D (Gokhberg & Fichtner, 2016). We exploit reciprocity, and by treating seismic stations as virtual sources we compute and store the wavefield across the domain. This gives us a strain database for all potential source-receiver pairs. We store the wavefield for more than 50 F-net broadband stations (www.fnet.bosai.go.jp). By assuming an impulse response as the source time function, the displacements are then promptly obtained by linear combination of the pre-computed strains scaled by the moment tensor elements.

With a feasible number of model parameters and the fast forward problem we infer the unknowns in a Bayesian framework. The fully probabilistic approach allows us to obtain uncertainty information as well as inter-parameter trade-offs. The sampling is performed with a variant of the Hamiltonian Monte Carlo algorithm, which we developed previously (Fichtner and Simutė, 2017). We apply an L2 misfit on waveform data, and we work in the period band of 15–80 s.

We jointly infer three location parameters, timing and moment tensor components. We present two sets of source solutions: 1) full moment tensor solutions, where the trace is free to vary away from zero, and 2) moment tensor solutions with the isotropic part constrained to be zero. In particular, we study events with significant non-double-couple component. Preliminary results of \textasciitilde Mw 5 shallow to intermediate depth events indicate that proper incorporation of 3-D Earth structure results in solutions becoming more double-couple like. We also find that improving the Global CMT solutions in terms of waveform fit requires a very good 3-D Earth model and is not trivial.