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NASTF: A Bayesian catalogue of source parameters from teleseismic body waves

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Large earthquakes and those in densely instrumented areas are now being studied in great detail and in extended-source frameworks like finite-fault or back-projection. However, smaller earthquakes (below $M_W \approx 7.5$) and especially remote ones with sparse data coverage are still approximated best by a point source. For earthquakes larger $M_W \approx 5.5$ it is generally possible to invert for the temporal evolution and describe it in the form of a moment rate or Source Time Function (STF).

A reliable STF is crucial for broadband waveform tomography. Its uncertainty is hard to quantify, especially since it is correlated with the estimated source depth, e.g. when surface-reflected phases are mapped into the STF. While the inversion for the STF and the moment tensor is linear, the depth inversion is inherently non-linear. Experience shows that data from shallow earthquakes can often be fitted well by several distinct depths. Therefore it is hard to linearize the inversion for the depth. We therefore propose a fully Bayesian inversion scheme for the Source Time Function, depth and moment tensor as follows:

1. The STF is parametrized in empirical source wavelets. Those wavelets are derived from a catalogue of STFs for intermediate size earthquakes, which were determined beforehand. The STF can be described by 8-10 weighting factors of these wavelets.

2. As a misfit criterion we use the waveform coherence in the *P*- and *SH*-window. While it is not possible to derive an Likelihood distribution for this measure analytically, we use a large number of synthetic waveforms calculated with catalogue source solutions to find such a Likelihood function empirically. This is then used to determine the Likelihood of any given solution in the ensemble.

3. The parameter space then has 14-16 dimensions, and is sampled with the Neighbourhood Algorithm. Therefore the inversion is derivative-free and not disturbed by the nonlinearity of the problem.

4. Synthetic waveforms are calculated using a reflectivity code on the *IASP91* mantle with local crust models from *CRUST2.0*. One forward solutions takes around 1 CPU-second.

Exhaustive sampling of the model space requires around 10^5 forward solutions to be calculated, which means less than one hour on a modern multicore computer. The resulting ensemble offers more than just a best solution, but rather probability density functions for all parameters, from which the extend of likely solution regions can be estimated.

While this method may be too intensive for rapid-source-determination, all kinds of broadband body wave studies could benefit from a reliable STF catalogue with actual uncertainties.