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A new Bayesian Earthquake Analysis Tool (BEAT)

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Modern earthquake source estimation studies increasingly use non-linear optimization strategies to estimate kinematic rupture parameters, often considering geodetic and seismic data jointly. However, the optimization process is complex and consists of several steps that need to be followed in the earthquake parameter estimation procedure. These include pre-describing or modeling the fault geometry, calculating the Green's Functions (often assuming a layered elastic half-space), and estimating the distributed final slip and possibly other kinematic source parameters. Recently, Bayesian inference has become popular for estimating posterior distributions of earthquake source model parameters given measured/estimated/assumed data and model uncertainties. For instance, some research groups consider uncertainties of the layered medium and propagate these to the source parameter uncertainties. Other groups make use of informative priors to reduce the model parameter space. In addition, innovative sampling algorithms have been developed that efficiently explore the often high-dimensional parameter spaces.

Compared to earlier studies, these improvements have resulted in overall more robust source model parameter estimates that include uncertainties. However, the computational demands of these methods are high and estimation codes are rarely distributed along with the published results. Even if codes are made available, it is often difficult to assemble them into a single optimization framework as they are typically coded in different programing languages. Therefore, further progress and future applications of these methods/codes are hampered, while reproducibility and validation of results has become essentially impossible.

In the spirit of providing open-access and modular codes to facilitate progress and reproducible research in earthquake source estimations, we undertook the effort of producing BEAT, a python package that comprises all the above-mentioned features in one single programing environment. The package is build on top of the pyrocko seismological toolbox (www.pyrocko.org) and makes use of the pymc3 module for Bayesian statistical model fitting. BEAT is an open-source package (https://github.com/hvasbath/beat) and we encourage and solicit contributions to the project. In this contribution, we present our strategy for developing BEAT, show application examples, and discuss future developments.