ESC2016-475, 2016
35th General Assembly of the European Seismological Commission

Automated moment tensor inversion with Bayesian approach and noise covariance matrix

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Focal mechanisms are important for understanding seismotectonics of a region, and they serve as a basic input for seismic hazard assessment. Usually, the point source approximation and the moment tensor (MT) are used. We developed a new, fully automated tool for MT inversion taking into account recent developments. It includes automated data retrieval, data selection according to noise level and presence of various instrumental disturbances, setting frequency ranges for each station individually according to its distance and event magnitude, and full-waveform inversion in space-time grid around hypocenter. The MT inverse problem is solved in a space-time grid whose size is automatically chosen according to the location uncertainty and magnitude. Grid search over time and space is effectively combined with analytical (least-squares) inversion of the moment tensor. Bayesian formulation of the problem is used, so not only the best solution is found, but also the full posterior probability density function. The marginal probability density for every parameter can be plotted. The covariance matrix in the Bayesian formulas is calculated from before-event noise. It yields an automated weighting of the stations according to their noise levels and also serves as an automated frequency filter suppressing noisy frequencies. The method has been tested on synthetic and real data. It was applied on a dataset from the Swiss seismic network and the results were compared with the existing high-quality MT catalog. To speed up the inversion, the time demanding tasks such as the Green's function calculations and the spatial grid search are parallelized. The software package is coded as much versatile as possible in order to be applicable in various networks ranging from local to regional. It shares some similarities with the broadly used ISOLA software in terms of the inversion methods and input/output file structures, but most codes have been re-written from the scratch for maximum computational efficiency (combing Fortran and Python, using ObsPy, NumPy, and MatPlotLib). Opposed to ISOLA, whose advantage is in a friendly manual processing of individual events using Matlab GUI, the new codes are intended rather for a massive automated application on large sets of earthquakes from a database, and/or for near real-time applications.