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Kinematic Point Source Moment Tensor Inversion Using a Hierarchical Bayesian Approach

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The seismic moment tensor (MT) reveals details about source processes within the Earth that cause earthquakes. Although uncertainties in MT inversions are important for estimating solution robustness, they are rarely available. When earthquake location is simultaneously recovered with the MT, uncertainties in structural Green's functions also need to be included in the method. The problem becomes nonlinear and uncertainties in the source mechanism cannot be calculated in a simple manner.

We have developed a method and software for a hierarchical Bayesian MT inversion to study moderate earthquakes and explosions generating waveform data at regional distances. The Bayesian inversion gives a posterior probability distribution of model parameters, based on prior knowledge about the MT and the model likelihood, determined by the data. MT uncertainties can then be estimated from the posterior probability distribution. The hierarchical Bayes approach enables us to recover the nature of the data noise and the weight of each waveform, treating them as unknowns in the inversion. Critically, data noise covariance matrix is implemented to account for measurement and theory errors. This knowledge, in turn, enables us to recover the solution within a reasonable range of uncertainty; in other words, it prevents us from "fitting the noise" that can lead to erroneous solutions and interpretation.

Synthetic experiments were performed to test the codes, particularly the retrieval of non double-couple components of the MT. A suite of synthetic and observed focal mechanisms was used to create the synthetic data. Additionally, we add noise to synthetic data (as a fraction of data rms) to test its effect on the inversion. Experiments are performed using uncorrelated Gaussian white noise, as well as using correlated noise.

Parameter space for the event mechanism is sampled exhaustively, while the code rapidly converges towards the input hypocenter location. Both the input mechanism and noise level were retrieved in the inversion. The codes are currently being applied on real data to test earthquakes in a variety of tectonic settings.