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Estimation of full moment tensors, including uncertainties, for earthquakes, volcanic events, and nuclear explosions

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A seismic moment tensor is a 3×3 symmetric matrix that provides a compact representation of seismic events within Earth's crust. We develop an algorithm to estimate moment tensors and their uncertainties from observed seismic data. For a given event, the algorithm performs a grid search over the six-dimensional space of moment tensors by generating synthetic waveforms at each grid point and then evaluating a misfit function between the observed and synthetic waveforms. 'The' moment tensor M for the event is then the moment tensor with minimum misfit. To describe the uncertainty associated with M, we first convert the misfit function to a probability function. The uncertainty, or rather the confidence, is then given by the 'confidence curve' $P(V)$, where $P(V)$ is the probability that the true moment tensor for the event lies within the neighborhood of M that has fractional volume V. The area under the confidence curve provides a single, abbreviated 'confidence parameter' for M. We apply the method to data from events in different regions and tectonic settings: small ($M_{\mathrm{w}} < 2.5$) events at Uturuncu volcano in Bolivia, moderate ($M_{\mathrm{w}} > 4$) earthquakes in the southern Alaska subduction zone, and natural and man-made events at the Nevada Test Site. Moment tensor uncertainties allow us to better discriminate among moment tensor source types and to assign physical processes to the events.