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# Error estimations for seismic source inversions

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The estimation of source parameters is essential for understanding the earthquake rupture phenomenon. It is also of the greatest interest to improve our knowledge of the tectonics and geodynamics. The estimated source models can in turn be used as inputs for various algorithms such as ShakeMap computation, tsunami modeling, stress tensor calculation, waveform modeling for tomography studies, etc. The source inverse problem can be formulated and solved in various ways depending on the nature of data (e.g. strong motion, body waves, surface waves, InSAR, GPS, microtectonics, etc.), the observation scale (e.g. regional, teleseismic), and the time at which it is performed after the event origin time (ranging from real time to the study of historical earthquakes).

Besides the type of used data, the quality of source inversion results is highly variable depending on many factors like the size of the event, its geographical location, its complexity, the amount of data and the way the data cover the source region (azimuth and/or distance). Here, like in any observational problem, the error estimation should be part of the solution. It is however very rare to find a source inversion solution which includes such component and the inversion algorithms themselves are generally not including proper error analyses. Our goal here is to stress the importance of such estimation and to explore different techniques aimed at achieving such estimations.

Formally, it is easy to distinguish two sources of error in this kind of problems. On one side we have the error induced by the more or less imperfect data. This information is carried, for example, by the covariance matrix for the data Cd which can be classically propagated into a covariance matrix for the estimated parameters. The second source of error, often overlooked, is associated with modeling error or, in other terms, the error in the theory. When assuming gaussian prior probability densities, this information is carried by the covariance matrix on the theory, Ct . This second contribution is of special relevance to the case of source inversion. In fact, it is a very common practice to fix some parameters (e.g. the source location, or the fault plane) and perform the inversion for another group of parameters (e.g. the focal mechanism or the orientation of the slip vector). In such cases, fixing some unknown parameters at certain values certainly contributes to the error on the final model. Both Cd and Ct are of the same dimension and it is well known that it is in fact CD = Cd + Ct which should be included into the error propagation process. Another key point which is practically always ignored is the possibility of having non diagonal elements of data covariance matrices. With the increasing volume of geodetic and seismological data it becomes necessary to explicitly take into account the non diagonal terms. We demonstrate here that this is not only a matter of convenience, but that it is absolutely necessary to take them into consideration in order to allow for a useful interpretation of the source models. We discuss the above by applying the W-phase source inversion algorithm (Kanamori and Rivera, 2008) to several recent large earthquakes (Samoa, 2009; Chile, 2010, etc).