Moment tensor inversion of small to moderate earthquakes in the Capital Region in 2004

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Abstract
The moment tensor solutions of 51 small to moderate earthquakes occurred in the Capital Region in the year of 2004 are obtained by inverting the broadband waveform data. Accordingly, other source parameters, such as scalar seismic moments, moment magnitudes, double-couple (DC) components and compensated-linear-vector-dipole (CLVD) components, are determined as well as fault parameters and stress-axis parameters. The inverted results are evaluated by groups of numerical tests.

Key words: Capital Region; small-moderate size earthquakes; moment tensor inversion
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Introduction
Focal mechanisms of earthquakes have been playing and will play an important role in the development of earth sciences. As early as in the 1960s, the fault-plane solutions of earthquakes were used in the investigation of stress-field direction (McKenzie, 1969). Over decades, a lot of studies associated with focal mechanisms of earthquakes have been made (Tapponnier and Molnar, 1976; Zoback et al., 1987; Xu et al., 1992; XU, 2001; Kubo and Fukuyama, 2003). The focal mechanism solutions in the earlier years were determined with the data of the first motion of P waves. Only a small number of earthquakes were processed for their focal mechanisms due to the limited number of usable stations. Since 1970s the waveform data has become usable in determining the moment tensor and focal mechanism solutions (Gilbert and Dziewonski, 1975; Patton and Aki, 1979). Meanwhile, the range of available data in determination of focal mechanisms had been greatly extended, such as data of free oscillation, surface wave, body wave and others.

As we have known, besides the fault parameters, other source parameters, such as seismic moment tensor solution, scalar seismic moment, moment magnitude, explosive component, compensated-linear-vector-dipole (CLVD) component and so on, can be obtained by means of moment tensor inversion. All these parameters can be used in other studies, for examples, relation-
ship between scalar seismic moment and occurrence rate (Frohlich and Davis, 1993; Sornette et al., 1996; Kagan, 1997), global distribution of non-double-couple events (Kawakatsu, 1991), types of earthquakes (Reasenberg, 1999), variation of potential energy in crust (Tanimoto and Okamoto, 2000) and relationship of focal mechanisms with time (Kagan, 2000), and so on.

In the period of the years 1995 to 2000, a number of regional or local digital seismic stations were established across China. It enables us to determine the moment tensor solutions and other associated source parameters by technique of moment tensor inversion using waveform data recorded in these stations. In this study, the moment tensor solutions and some other relevant parameters of the small-moderate size earthquakes occurred in the Capital Region in the year of 2004 are determined by the moment tensor inversion.

1 Method

In frequency domain, the displacement at the observation point \( r \) caused by a point source described with a moment tensor and located at the origin of a coordinate system is expressed with

\[
u_i(r, \omega) = G_{ij,k}(r, \omega) \cdot M_{jk}(\omega)
\]

where \( \omega \) is angular frequency frequency; \( u_i(r, \omega) \), the spectrum of observed displacement; \( M_{jk}(r, \omega) \), the spectrum of the moment tensor; and \( G_{ij,k}(r, \omega) \), the spectrum of Green’s functions. That means the spectrum of observed displacement equals to the multiplication of the spectrums of Green’s functions with that of the moment tensor. Inversely, the spectrum of moment tensor equals to the spectral division of the observed displacement by Green’s functions.

For smaller earthquakes, a suitable frequency band could be found so that in this band the source time functions (STF) of the smaller earthquakes can be considered as a simple pulse which can be substituted with a Dirac-\( \delta \) function. In this case, the equation (1) becomes

\[
u_i(r, \omega) = G_{ij,k}(r, \omega) \cdot M_{jk}
\]

It means the moment tensor describing the point source has nothing to do with frequency.

In real work, a suitable band-passed filter may be selected, so that the observed data and the correspondent Green’s functions have the same frequency band and the STF satisfies the requirement of Dirac-\( \delta \) function. As shown in Figure 1, the spectra of the unfiltered observed waveform data and Green’s functions look obviously different, and the corner frequencies of the observed data are different from those of the Green’s functions (Figure 1b). However, the spectra of the filtered observed data and Green’s functions look very similar, and their corner frequencies are in good agreement (Figure 1c). In this case, the STF of the correspondent event can be approximately considered as a Dirac-\( \delta \) function while the main feature of the observed data (Figure 1a) and Green’s function (Figure 1d) remains, and the main information to be used to determine the moment tensor solution is still existing and undamaged, as we noticed (Figure 1d).

2 Observed data and Green’s functions

In the period of the years 1995 to 2000, China Earthquake Administration set up 107 digital seismic stations in the regions of Beijing, Hebei and Tianjin, which is called the Capital Region, including 48 stations with digital broadband seismograph and 59 stations with digital short-period seismographs. In this study, the broadband waveform data of the events located in the Capital Region (113°E~121°E, 37°N~41.5°N) in the year of 2004 were processed, and 51 of these events