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Estimating the macroseismic parameters of earthquakes in eastern Iran

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ABSTRACT

Macroseismic intensity values allow assessing the macroseismic parameters of earthquakes such as location, magnitude, and fault orientation. This information is particularly useful for historical earthquakes whose parameters were estimated with low accuracy.

Eastern Iran (56°–62°E, 29.5°-35.5°N), which is characterized by several active faults, was selected for this study. Among all earthquakes occurred in this region, only 29 have some macroseismic information. Their intensity values were reported in various intensity scales. After collecting the descriptions, their intensity values were re-estimated in a uniform intensity scale. Thereafter, Boxer method was applied to estimate their corresponding macroseismic parameters.

Boxer estimates of macroseismic parameters for instrumental earthquakes (after 1964) were found to be consistent with those published by Global Centroid Moment Tensor Catalog (GCMT). Therefore, this method was applied to estimate location, magnitude, source dimension, and orientation of these earthquakes with macroseismic description in the period 1066–2012. Macroseismic parameters seem to be more reliable than instrumental ones not only for historical earthquakes but also for instrumental earthquakes especially for the ones occurred before 1960. Therefore, as final results of this study we propose to use the macroseismically determined parameters in preparing a catalog for earthquakes before 1960.

1. Introduction

Detailed and accurate information of earthquakes can be used to understand the seismicity and also to assess seismic hazard of a region. Macroseismic Data Points (MDPs) with or without complete descriptions could be one of the best sources of information to estimate the earthquake parameters especially when instrumental records are lacking.

There are several documents with descriptions of MDPs for some Iranian earthquakes. The intensity values were reported in four types of intensity scales; one 5° scale (Ambraseys and Melville Scale: AMS) (Ambraseys and Melville, 1982) and three 12° scales: the Modified Mercalli (Wood and Neumann, 1931; Richter, 1958), the Medvedev-Sponheuer-Karnik (MM; MMI) (Medvedev et al., 1964) (MSK), and the European Macroseismic Scale (EMS) (Grünthal, 1992, 1998). In this study, descriptions of some of these earthquakes were collected using a large set of available documents (books, reports, and articles) [e.g. Zare and Memarian (2003), Ambraseys and Melville (1982), and Berberian (1976, 1977, 1981)].

In order to be used for estimating earthquake parameters, the intensity values have to be provided in a uniform intensity scale. In this study, the intensity values were re-estimated for MDPs and earthquakes with descriptions, based on EMS intensity scale nthal (1992, 1998); nthal (1992, 1998). This scale is the newest and more complete macroseismic scale including details on damage for different types of buildings. Moreover, to even consider all reported environmental effects, the Environmental Seismic Intensity (ESI) scale (Michetti et al., 2004, 2007; Guerrieri et al., 2015) was also used in re-estimating some intensity values, especially in sparsely populated areas where information on damage is lacking.

In the current literature, there are mainly three methods that can be used to determine the earthquake parameters using macroseismic datasets. The first one, developed by Bakun and Wentworth (1997), uses a grid search to find the best results. The results of this method are sensitive to the spatial distribution of intensity data; so, with poor data, it sometimes locates the macroseismic epicenter away from the area with maximum intensities. Epicentral uncertainties are modelled as contour lines of different confidence levels of the residuals of the calculated

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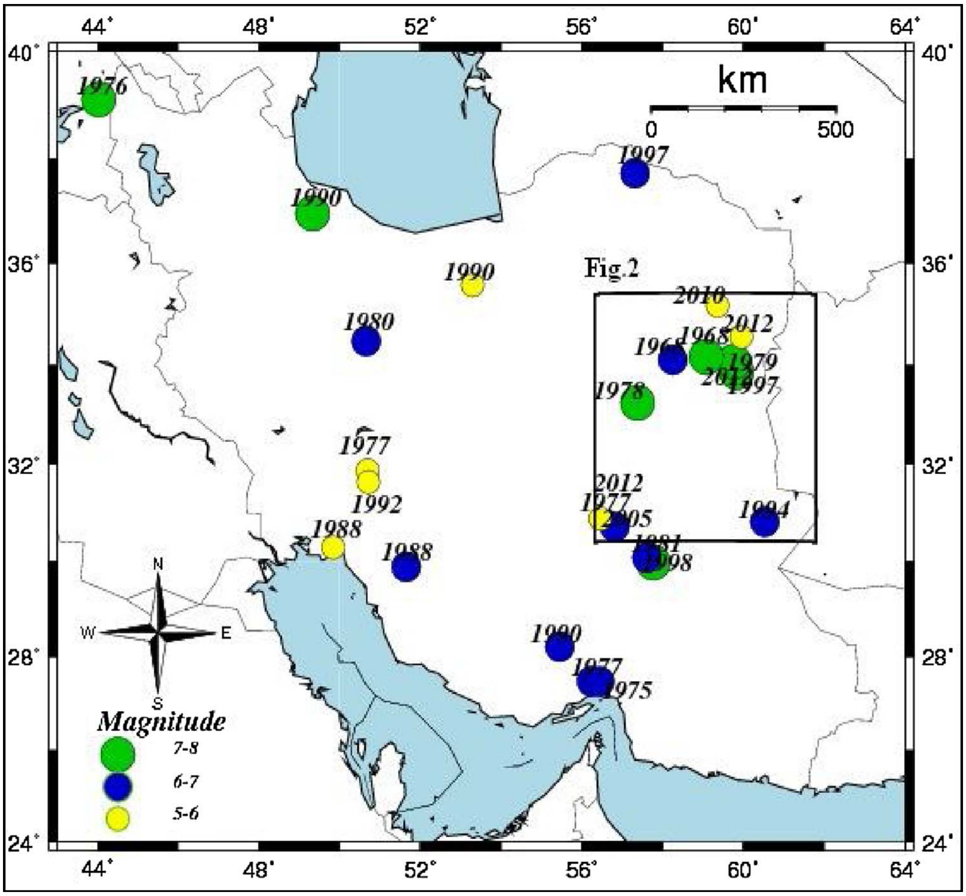

Fig. 1. Map of Iranian instrumental earthquakes used in this study. Rectangle indicates the area (Eastern Iran) which macroseismic parameters are computed in this study.

magnitudes; this information could not be easily included in a parametric catalog (Gomez-Capera et al., 2014). The second one (Boxer method) developed by Gasperini et al. (1999, 2010) computes the epicenter as the barycenter of the distributions of sites with the highest intensity value and is scarcely sensitive to irregular distribution of intensities. Even with few MDPs, its calculated epicenter is relatively stable and the method provides consistent uncertainties for all parameters (Gomez-Capera et al., 2014). The third one (MEEP method) introduced by Musson and Jiménez (2008) does not provide stable results, especially for moderate to high magnitudes (Gomez-Capera et al., 2014).

As the number and distribution of MDPs of Iranian earthquakes are usually poor, Boxer “Method 0” (see Gasperini et al., 2010) was selected in this study to determine the earthquake parameters.

2. Methodology

Boxer method was proposed by Gasperini et al. (1999) as an evolution of the algorithm initially developed by Gasperini and Ferrari (1995). Boxer was originally proposed for Italy; but, starting with the 4.0 release, it can even be used in other areas of the world because a calibration procedure is included in such version. Among the others, “Method 0” of Boxer requires less information for each earthquake and uses “robust” estimators (like the trimmed mean) that are scarcely sensitive to outliers. The strategy of this method involves five steps: 1) locating the earthquake, 2) assessing the earthquake moment magnitude (Mw), 3) computing the source dimensions (length and width), 4) estimating the source orientation (azimuth), and finally 5) representing the source.

The algorithm described by Gasperini and Ferrari (1995, 2000) computes the epicentral intensities (I_0) as the largest observed intensity if there are 2 or more MDPs with such highest intensity. In other cases, I_0 is set to I_{max}-1. The location coordinates are computed as the trimmed means (that is, the arithmetic average of the data that falls between the twentieth and eightieth percentiles) of the coordinates of MDPs with the highest intensity values (Gasperini et al., 1999). The magnitudes are computed based on Sibol et al. (1987) relationship for each isoseismal. Then, the magnitude of each earthquake is computed as the weighted trimmed mean of the magnitudes obtained from different isoseismals.

The earthquake seismogenic source could also be computed as a rectangular region or a “box” (from which comes the name Boxer). This box is centered in the calculated epicenter and the orientation is computed as the weighted axial mean of the distribution of the axial orientations (Gasperini et al., 2010). Empirical relationships of Wells and Coppersmith (1994) for all kind of focal mechanisms are used to calculate the subsurface rupture length (RLD) and the down dip rupture width (DW) based on the moment magnitude. The box is finally represented graphically as the surface projection of the fault by assuming a dip angle of 45° which is about the average value for dip-slip faults.

The uncertainties of the parameters are estimated using formal method and bootstrap simulations (Efron and Tbishirani, 1986; Hall, 1992). Formal uncertainties of epicentral coordinates are calculated as