Temporal Variations of Seismic Parameters in Tehran region

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ABSTRACT
The study of earthquake precursors can lead to deliver an entirely measurable, time varying estimation of the coming events which is strongly based on physical and geological principals and fully responsive to any future examination. The temporal variation of the seismic parameters such as "a" and "b" values, in the Gutenberg–Richter formula logN = a - bM, as well as some details of the pre-shock accelerating moment release (AMR) is investigated in the vicinity of the Tehran city. Some pre-shock accelerating moment release (AMR) can be observed before the bigger events in the region which can be aggregated with the signals of time variation of the GR b-value. The results suggest that a combination of these physical precursors has a potential which could be employed in a medium term earthquake warnings.

Keywords: Precursors, Accelerated Moment Release, b-value variation, Earthquake

1 INTRODUCTION

Understanding the dynamics of seismic activity is an essential step to the investigation of the earthquake process. Several models have been used in the past to test the typical assumptions and effective parameters inherent in the complicated dynamics of the seismic activity and their relative variability. Among them, broad characteristics of earthquake precursors are also widely studied, particularly the time variation and spatial distribution which are truly important phases in forecasting the probable coming events. Numerous observational and theoretical methods on the properties of earthquake parameters have been investigated to find a persuaded precursory seismic signal (Habermann, 1981; Keilis-Borok, 1982; Shaw et al., 1997; Shebalin et al., 2000). But no assured predictive single precursor has been proven yet. Here, the intention is to analyze the seismic parameters, which can possibly reveal some aspects of the geodynamic characteristic in Tehran vicinity. Therefore, the temporal variation of the seismic parameters, such as the number and the time clustering of earthquake occurrence, *b*-value estimates and the released energy of an event showing the characteristic of earthquakes is considered. These parameters as physical seismic signals are associated with the seismogenic procedure and so contains crucial facts that are valuable in the interpretation of an earthquake phenomenon (Mogi, 1962; Aki, K., 1965; Utsu, 1965; Scholz, 1968; Smith, 1981; Molchan and and Dimitrieva, 1990; Wiemer and Wyss, 2002). The temporal variation of the Guttenberg-Richter *b* value (Gutenberg and Richter, 1942), as well as some details of the pre-shock accelerating moment release (AMR) is monitored in Tehran region. The analysis are performed by using the catalogue of the Iranian Seismological in the Tehran region and contain major known faults around the city.

2 Data

The region examined in this study (Fig.1-a) is limited by latitudes 35^o-37^o N and longitudes 50^o-53^o E and includes the city of Tehran and all known faults around it. The data used in this study is reported by Iranian Seismological Center from the Institute of

Geophysics, University of Tehran covering a time period of about 20 years from January 1996 to June 2015. The total 12257 event with any detected magnitudes are used in the analysis. Fig.1b illustrates the epicenters of the events in the required time period.

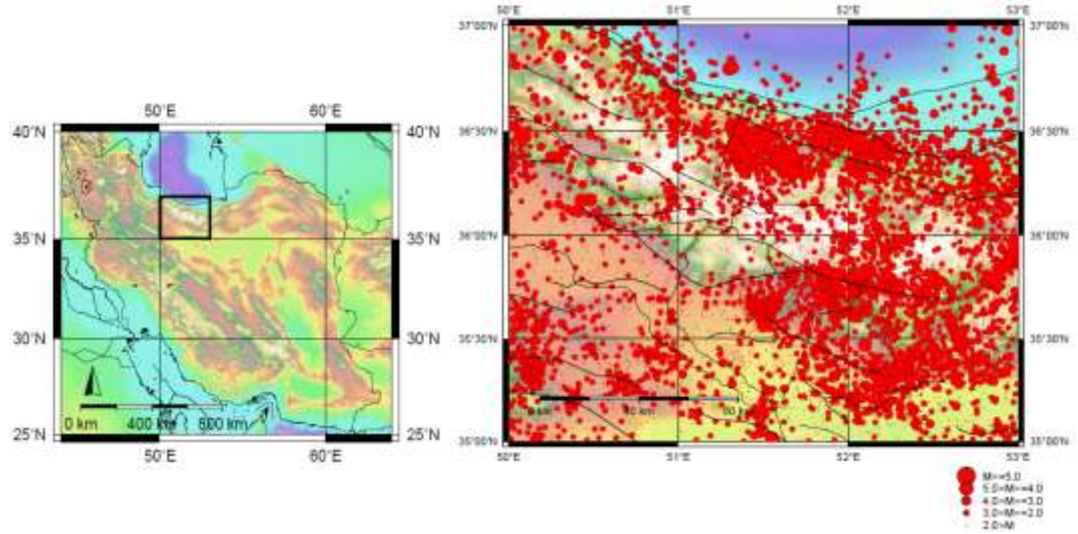

Figure 1. a- The studied area. b- Epicenters of the events in the region from January 1996 to June 2015.

3 ACCELERATED MOMENT RELEASE (AMR)

Mogi (1981) observed a regional increase in seismicity before great earthquakes, including an increase in the overall level of seismicity in the crust surrounding the future rupture zone, in conjunction with quiescence, or a relative shortage of events, along or near the fault. Ellsworth et al. (1981) also observed an increase in the rate of M5 events over a broad region in the years preceding the 1906 San Francisco earthquake. This particular pattern of precursory seismicity appears to accelerate with the approach of the mainshock (AMR) (Bowman and King, 2001; Bowman et al, 1998; Sornette and Sammis, 1995; Bufe and Varnes, 1993) and is defined by the equation

$$\varepsilon(t) = A + B(t_f - \mathrm{t})^m, \quad (1)$$

ε(t) has been interpreted as either the accumulated seismic moment, the energy release or the Benioff strain release within a specified region, from some origin time t0, up to time t.

$$\varepsilon(t) = \sum_{1}^{N(t)} E_i^k, \quad (2)$$

is the number of events in the region between t_0 and t, E_i is the energy release from the i^{th} event, and k=0, 1/2, 1. A is a constant that depends on the background level of activity, t_f is the time of the mainshock, *B* is negative and *m* is a constant value.

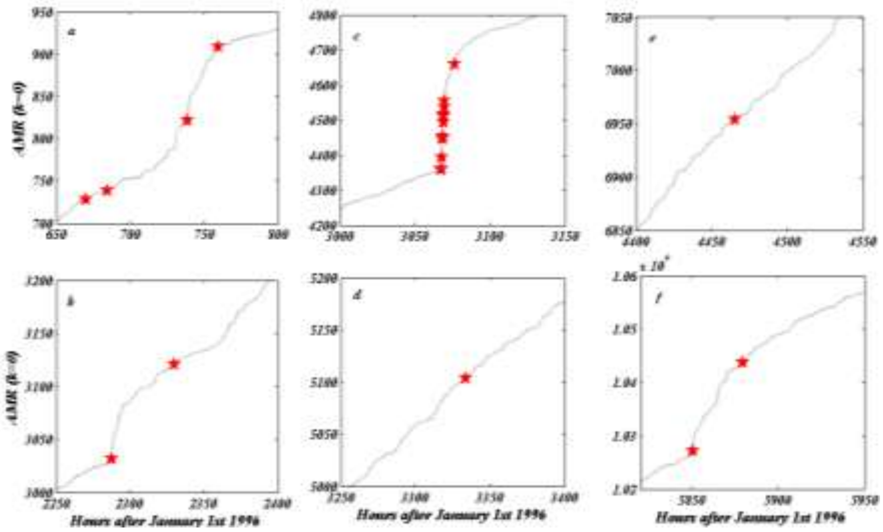

Figure 2. Accelerated Moment Release of the Earthquakes (k=0 in eq.2), (Red stars shows the times in which an earthquake with the magnitude bigger than 4.5 occurred)

Ben-Zion and Lyakhovsky (2002) analyzed the deformation preceding large earthquakes and obtained a 1-D analytical power-law time-to-failure relation for AMR before big events. They found that phases of AMR exist when the seismicity occurring immediately before a large event has magnitude-frequency statistics over several ranges of magnitude. These and similar results of Turcotte et al. (2003) and Zoller et al. (2006) are consistent with observed seismic activation before some large earthquakes.

In this study, AMR is calculated to all three values of k (eq. 2). Fig.2 shows the results for k=0 and it clearly shows that although there is no change in the slope of AMR in the subfigure of *d* and *e*, but it deviates from the linear behavior in other cases. In all cases the slope of the line return back to the background slope when the sequence of higher activity ends.

4 TEMPORAL VARIATION OF THE b-VALUE PARAMETER

Statistical seismologist frequently use a power low frequency-magnitude distribution of earthquakes, widely known as the Guttenberg-Richter relation (Gutenberg and Richter, 1942).

$$\log N = a - bM \qquad (3)$$

which predicts the number of earthquakes larger than a given magnitude. In this equation, M is magnitude, *a* and *b* are constants and *N* is number of earthquakes equal to or larger than M. During long enough periods of time and over vast enough areas, the *b*-value is always close to one. But, it might vary form unity for shorter time intervals and smaller restricted areas.

Researchers observed considerable deviations in the *b*-value over different ranges of magnitude and in various locations (Wiemer and Wyss, 1997; Monterroso, 2003; Dasgupta et al., 2007; Nuannin et al., 2012). This deviation might be due to the stress increase, before the occurrence of an earthquake (Scholz, 1968; Wyss, 1973) which leads to a lower *b*-value around the hypocenters of the coming events. Or it might be related to the amount heterogeneities or fracture density close to future rupture (Mogi, 1962; Sobiesiak et al., 2007). In this study, the temporal variation of *b*-value is monitored close to bigger events in the area. In Fig. 3, the variation of the *b*-value close to the main shock in the series of the events is illustrated. In this figure, it is obvious that in the cases where two large events are occurring close to each other, after the occurrence of the first event the b-value does not drop quickly.

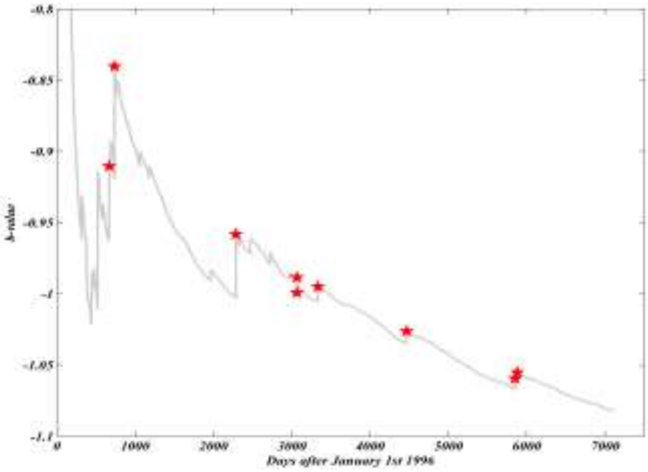

Figure 3. Temporal variation of the b-value over time (Red stars shows the times in which an earthquake with the magnitude bigger than 4.5 occurred)

5 CONCLUSION

In summary, temporal variation of two different seismic parameter prior to larger events in the catalogue of earthquake around the city of Tehran are investigated. The results of the analysis of short-term variations in AMR signal prior to the considered earthquake shows that its linear behavior start to change around the main events in the series. Although in some cases the deviation starts with large event, but always AMR signal returns back to its linear behavior after the sequent of large events. In addition, for the cases where two large events are occurring close to each other, the b-value does not drop quickly after the occurrence of the first event. The results suggest that the monitoring of the aggregation of these physical parameters along with the combination of other seismological and geophysical parameters has the potential which could be employed in a medium term earthquake warnings.

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