Applying LDF such an Innovative method on time series of soil temperature in earthquake prediction

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Abstract

Rise in temperature occurred after soil temperature was measured in different time series. In this article, LDF (logarithmic derivative filter) innovative method is applied to detect anomalies. This method tests soil temperature time series for 12 earthquakes in Iran with magnitudes of either five or greater than five. Results from this method were collected. Based on the results of LDF method and consequently applying of statistical indicators, average and standard deviation before all the great event of case study, from day one up to the month before the main quake, anomalous behaviors were revealed. A correlation between anomalies and earthquakes was observed.

Keywords: Earthquake prediction, LDF parameter, anomaly detection, Thermal precursor.

1- Introduction

Due to the complicated behaviors of Earth's mechanical and dynamical structure and a limitation of interior data, there are rarely any desirable results found on earthquake prediction. However, there are reports on physical and even chemical variations during an earthquake which may relates many parameters to earthquake activities. These variations include, but are not limited to: changes in Radon concentrations (Crockett and Gillmore, 2010; Pulinets and al, 1997), change in resistivity (Quian, 1985), vertical movements (Mogi, 1985), earthquake clouds (Shuguang and Guangmeng, 2012), groundwater flow (Yamaguchi, 1978) and temperature variation related to tectonic Activities (Kamali, Bidokhti, and Amiri, 2009; Rezapour, Bidokhti, and Fattahi, 2007; Tronin, Biagi, Molchanov, Khatkevich, and Gordeeev, 2004; Zhao, Ma, and Li, 2008). Thermal anomalies on time and places of earthquakes are also reported by satellite studies with desirable resolution (Akhondzadeh, 2014; Choudhury, 2005; Saradjian and Akhoondzadeh, 2010; Saraf, Rawat, Choudhury, Dasgupta, and Das, 2009; Tramutoli *et al*., 2012). Earthquake activity changes in Earth's local sub-surface resistivity, electric and magnetic potentials, Radon gas, stress and strain, friction, water flow, et cetera, altogether cause change in local thermal structure. No matter how much each factor may affects the temperature, but the integration of their effects in time of earthquake can have some other effects on sub-surface temperature. The key question is whether there is a parameter relating this thermal anomaly to the earthquake parameters. Below is the introduction of logarithmic derivative filter method such as innovative filter for twelve earthquakes in Iran. These methods were used to find sources of temperature anomaly and to predict some characteristics of the earthquakes.

2- Methodology

In this study, soil temperature is recorded 3 times a day with accuracy of plus or minus 0.2 OC. Atmospheric factors normally have an effect on the temperature of shallow soils (5 to 30 cm from the surface). Therefore, in this paper, the temperature of soil that is 100 cm below the ground is measured in order to decrease chances of atmospheric affects disrupting the results.

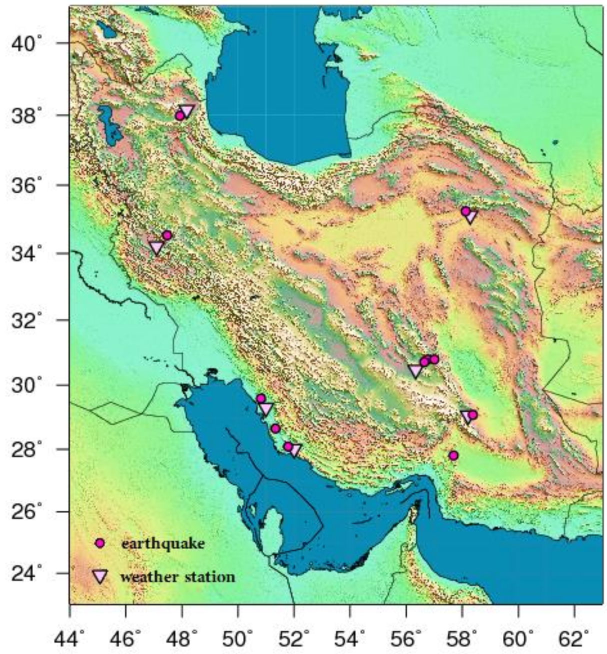

Figure 1) Location of Soil weather stations and earthquakes.

Considered earthquakes must have agreed to Dobrovolsky Law related to the closest station. In Dobrovolsky radius (Eq. 1), R and M are radius (Km) and Magnitude, respectively; where R shows effective radius of earthquake (Dobrovolsky, Zubkov, and Myachkin, 1979).

According to geographic coordinating of weather station that is mentioned in Table 1 and by applying the Dobrovolsky law, effective radius of earthquake with distance of earthquake epicenter from weather station are compared and earthquake with the best condition is selected. Also, figure 1 shows locations of weather station and earthquake epicenter.

The heat wave below the surface dampens very quickly due to daily variations. Although, any changes in temperature in deeper parts are not due to short period surface heat waves (Kamali *et al*., 2009). Therefore, temperature of soil at one meter depth is measured. In the next step, anomalous behavior is detected.

Table 1) Information about Location of Stations and earthquakes and earthquake information.

Earthquake	Date	Mag.	Depth	Lon.	Lat.	Station Lon.	Station Lat.	Dobrovolsky radius	τ
Ardabil	28-02-1997	6.1	12	47.93	37.99	48.17	38.15	420	1
Ardabil	02-03-1997	5.3	15	37.98	47.93	48.17	38.15	190	1
Boushehr	24-09-1999	5.3	14	51.34	28.65	50.50	28.59	190	2.8
Boushehr	27-05-2003	5.3	15	50.82	29.59	50.50	28.59	190	2.8
Boushehr	02-03-2004	5.1	15	51.16	28.90	50.50	28.59	156	2.8
Bam	26-12-2003	6.5	13	58.38	29.08	58.21	29.06	624	2.65
Kashmar	02-02-2000	5.3	23	58.12	35.24	58.28	35.12	190	2.85
Zarand	22-02-2005	6.4	14	56.76	30.80	56.34	30.48	565	2.25
Zarand	01-05-2005	5.1	14	57	30.80	56.34	30.48	156	2.25
Zarand	14-05-2005	5.2	14	56.65	30.72	56.34	30.48	172	2.25
Bandare Daier	13-09-2000	5	15	57.69	27.80	51.56	27.50	141	2.85
Bandare Daier	14-01-2004	5.4	13	51.79	28.08	51.56	27.50	210	2.85
Kermanshah	24-12-2002	5.2	30	47.47	34.54	47.09	34.21	172	2

2.1- LDF such an Innovative Filter

In the first step of LDF application, 273.15 Kelvins is added to the first time series. This is (because Log function nearby 0 value has an irregular behaviour, so degrees Kelvin preferred rather than degrees Celsius Next, log function with the base 10 is applied on time series and then Logarithmized time series is differentiated. Log function causes that data to be quantized, so differential cloud changes fluctuates around time axis.

After application of LDF on time series, anomaly detection is the next important issue. In this part, statistical anomalous range is needed. This range was obtained by Eq. 2:

$$\bar{M} \pm \tau\sigma \qquad (2)$$

In equation 2, the average of time series is calculated. Then, anomaly range is multiplied by the standard deviation. Finally, the result is added to/subtracted from the mean of time series. Value for anomaly range is calculated using iterative process of each region which can be found on Table 1.

3- Results

Figures 2 to 11 illustrate LDF parameter time series using anomaly detection method for 12 earthquake in Iran. As it is clear in those figures, prior to earthquakes larger than 5, anomalies are appeared. Since atmospheric conditions have the least effect on depth of one meter and larger, we predict that earthquakes caused anomaly behaviors.

Anomalies can be predicted from one day to one month before the main quake occurs. One of the interesting points about the anomalies is the fact that in the warmer months of the year, May to mid-October, anomalies seem to be sharper.

Another characteristic of this time series of actions LDF, is that the day before most of the earthquakes (8 cases), minimum and maximum temperature is reached. Since the LDF parameter is related to temperature, so the temperature anomalies behaviors (maximum and minimum) are in good agreement with previous studies.

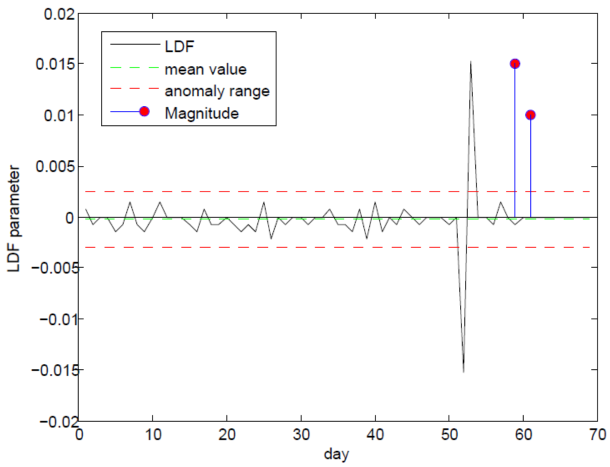

Figure 2) LDF parameter of Ardabil earthquakes (from 1/1/1997 to 10/3/1997).

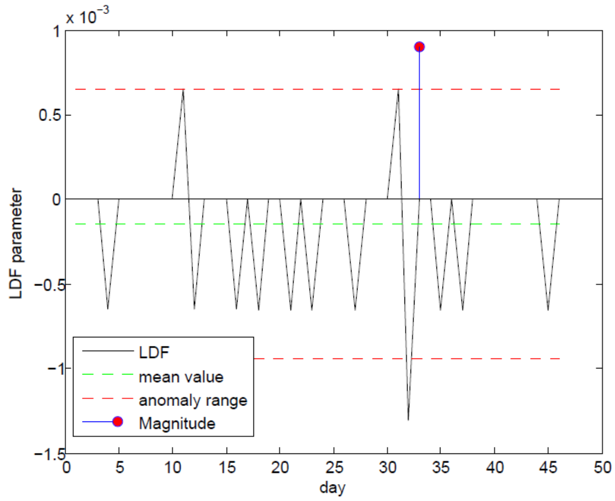

Figure 3) LDF parameter of Boushehr earthquake (from 24/8/1999 to 9/10/1999).

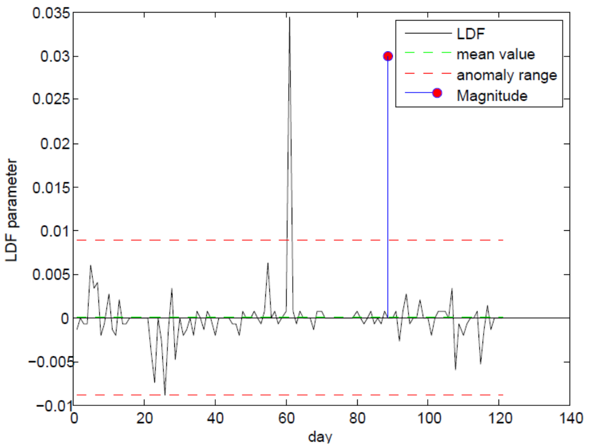

Figure 4) LDF parameter of Boushehr earthquake (from 1/3/2003 to 30/6/2003).

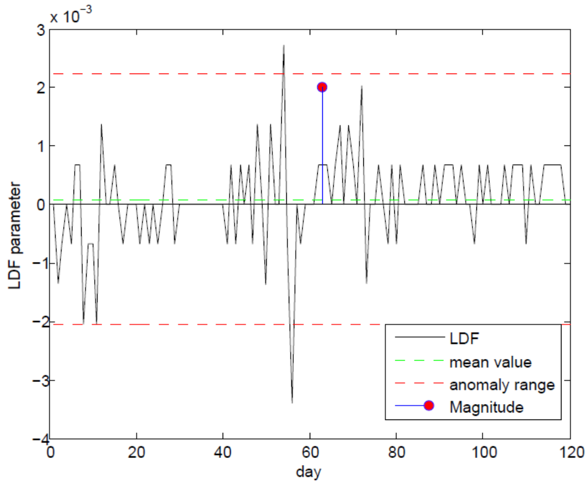

Figure 5) LDF parameter of Boushehr earthquake (from 1/1/2004 to 30/4/2004).

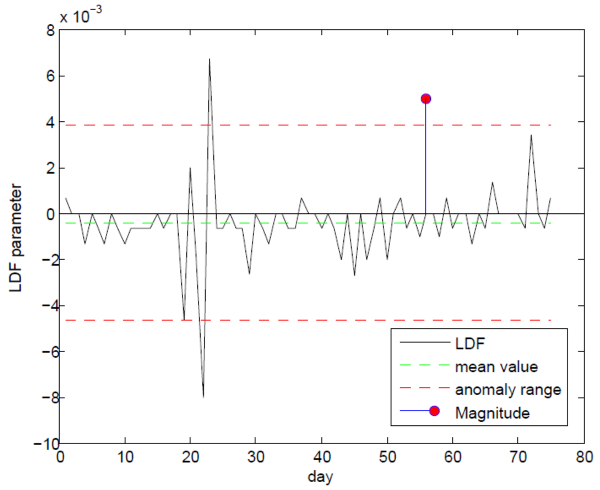

Figure 6) LDF parameter of Bam earthquake (from 15/10/2003 to 31/12/2003).

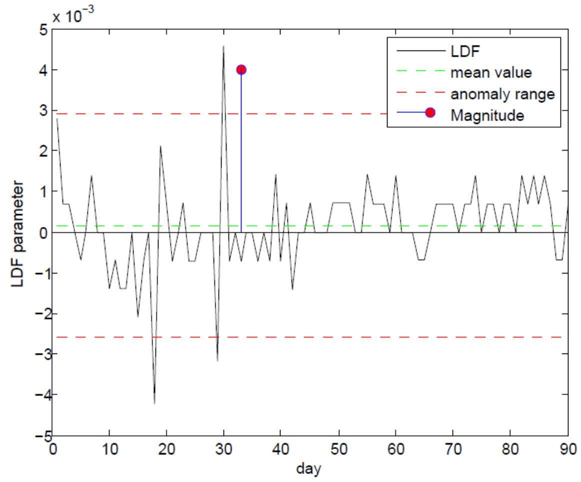

Figure 7) LDF parameter of Kashmar earthquake (from 1/1/2000 to 31/3/2000).

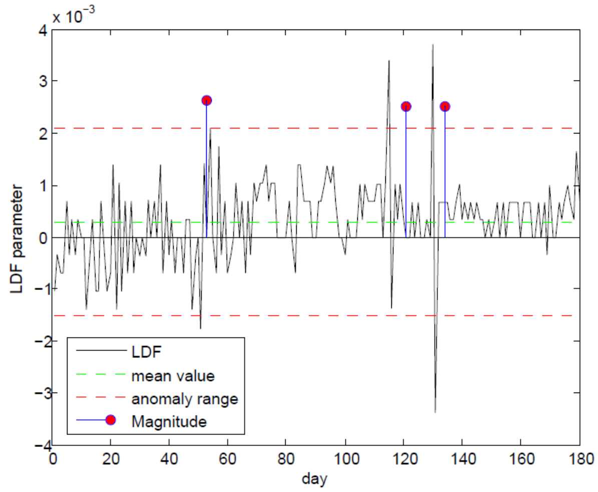

Figure 8) LDF parameter of Zarand earthquakes (from 1/1/2005 to 30/6/2005).

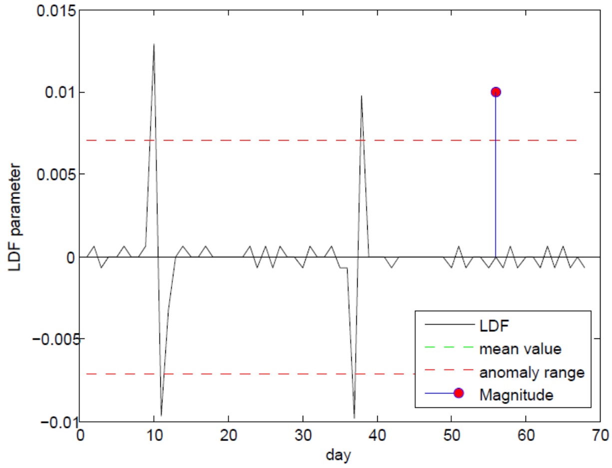

Figure 9) LDF parameter of Daier earthquake (from 20/7/2000 to 25/9/2000).

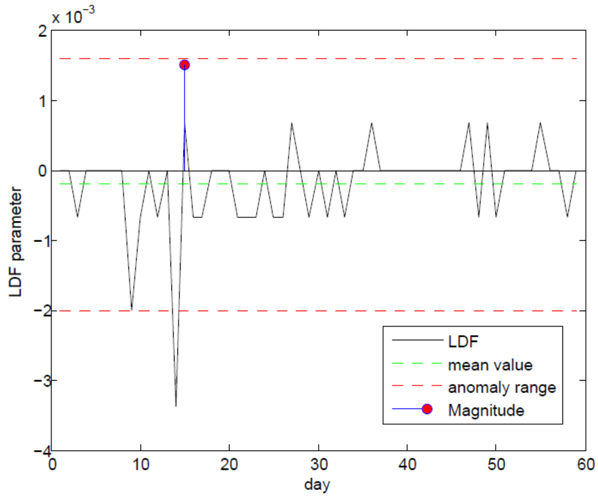

Figure 10) LDF parameter of Daier earthquake (from 1/1/2004 to 1/3/2004).

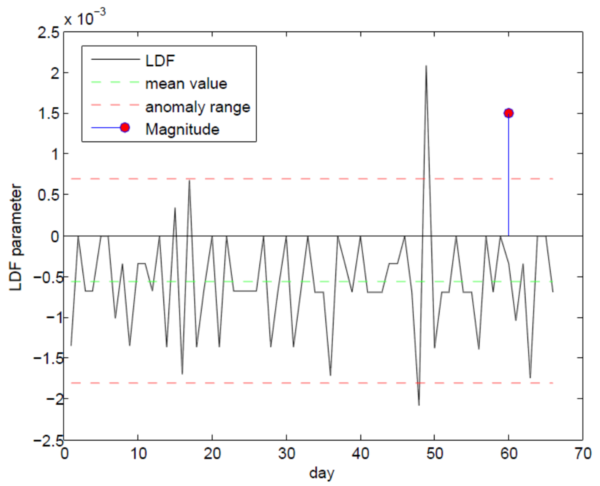

Figure 11) LDF parameter of Kermanshah earthquake (from 26/10/2002 to 31/12/2002).

4- Conclusions

In this study, the applications of LDF such as innovative filter to identify anomalies were used. Results prove that this method is fairly effective. Also it follows that in the warmer months of the year, this precursor could have acceptable solutions for the early warning issue.

In this study, there was a limitation with the distance of epicenter of major earthquakes and weather station. This problem can be solved by adding weather stations to more locations in Iran. Also, it must be mentioned that continuous monitoring of temperature by buried thermometer in soil may cause large temperature anomalies.

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