Reviewing precursors for the November 2021 Fin double-earthquakes

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ABSTRACT

Precursors as informer pioneers of near future occurrence of earthquakes, are very diverse in their natures. We examined three short term possible precursors contain foreshocks, b-value variations, and amplitude abnormalities in the Very Low Frequency (VLF) radio signals for the November 14, 2021 Fin double-earthquakes. By searching earthquakes one degree on each side of the hypocenter location in the IrSC, IIEES and BHRC catalogues, those data for the reviewing foreshocks were provided, then they analyzed by use of ZMAP for the b-value changes. Whereas, in the BHRC accelerometer portal reported 8 events before the main shock times, none of them are not in the other catalogues. The temporal b-value variations from the normal, shown non sharp fits to the rises or falls of the seismicity as an expected indicator. Some b-value in accordance with the seismic up and down rate tracks, have high spatial uncertainties. We observed some amplitude anomalies in the VLF received signals from 2σ criterion in about 4 days before and up to 5 days after the main shock times. Albeit, in follow the null hypothesis, for verifying (and not refused) the relations, are needed to be qualified data. Therefore, the reliability of the studied precursors completely dependent to the standard data, that sufficient-precise instruments for their observations and recording are vital requirement. It is also hoped that with the help of such reviews, necessity and importance of the data quality and improving of their acquisitions, be defined carefully and verified. There can be used of those types of reliable and high quality data in the pre-earthquake signals analyzing and or even reasonable prediction, if it possible in the future as valuable achievement.

Keywords: Earthquake, Precursor, Foreshock, b-value, VLF radio signals

INTRODUCTION

The northern coastal areas of the Persian Gulf, as part of the tectonic structure of the Zagros in the zone of collision with the Arabian plate, are prone moderate to large earthquakes. In the following of this background trend, two earthquakes occurred about one minute apart with epicenters around the small town of Fin, north of Bandar Abbas, in November 14, 2021 (1400/08/23 in the Persian Calendar). The locations of two earthquakes (27.56˚ N, 56.13˚ E), the origin times (the first 12:07:04 and the second 12:08:38) and the magnitudes (the first 6.4 and the second 6.3, both in the M_N magnitude scale) are reported preliminary by the Iranian Seismological Center (IrSC), then some parameters are modified later. The estimated characteristics of these earthquakes by Iranian seismological centers such as the International Institute of Seismology and Earthquake Engineering (IIEES), the accelerometer network of the Building and Housing Research Center (BHRC), and internationally (e.g., USGS, NEIC, Harvard Centroid Moment Tensor solution, CMT), have some differences that are not addressed here, because of less important role for the earthquake precursors reviewing.

Foreshocks are considered one of the most promising indicators that a large earthquake is imminent (Jones and Molnar, 1979) and the most common precursory which inherently difficult to identify them as foreshocks when they occur (Bouchon et al., 2013). The earthquake precursors (EP) are very diverse in nature and wide variety of physical phenomena that reportedly before some earthquakes (Geller 1997; Wyss and Booth 1997; Wyss 1997). Cicerone et al., 2009, mentioned that these phenomena include electric and magnetic fields, groundwater level changes, gas emissions, temperature changes, surface deformations, and anomalous seismicity patterns. The foreshock precursors are smaller earthquakes, well studied by ground-based seismic

instruments, which are preceded within hours, days or weeks of a great earthquake as the premonitory seismic activities. Seismic observations exhibit the presence of abnormal b-values prior to numerous earthquakes. The temporal variation in b-value is one of significant precursors for volcano activities and earthquake occurrences, Wang et al., 2016 and some references therein. The lithosphere-atmosphere-ionosphere coupling and interactions (LAI coupling) that following by effects of the seismic activities on the LF and VLF radio sky waves, are presented by several authors, that emphasized in Biagi et al., 2009. The work of Hayakawa et al., 1996 which eliminated the LF/VLF effected signals by the Kobe earthquake 1995, Japan, may be one of the first documentation of this precursory in the research field. How radio signals are distributed in the ellipse containing the Fresnel Zone and the effect of the active seismic environment on the ionosphere layers and the change in phase and amplitude of the radio signals are well described by Hayakawa 2015. We have examined three short term (hours up to days and weeks before an earthquake occurring) possible precursors contain foreshocks, b-value variations, and amplitude abnormalities in the received 18,200 Hz VLF radio signals for the November 14, 2021 Fin double-earthquakes. These selections has performed because of the easy access to available data as well as proper time required to processing and analysis for the upcoming conference submission.

METHODOLOGY, DATA AND PROCESSING

We selected three short-term pre-earthquake, and limited samples among several possible EP, contain probable related foreshocks of the earthquakes (i), b-value variations (ii) and an electromagnetic-limited frequency band, 18200 Hz of very low frequency (VLF) radio-signal amplitude anomalies (iii). For the foreshocks reviewing, we searched the available earthquake catalogs containing IrSC (http://irsc.ut.ac.ir/bulletin.php) and IIEES (http://www.iiees.ac.ir/en/eqcatalog/). Also, we searched in the BHRC accelerometer catalogue for probable foreshocks (***https://smd.bhrc.ac.ir/fa/search/) and found 8 events (1st at 20:23 UT, 13 November 2021) before the first Fin main-shock as they shown in Table 1 and Fig. 1. In the table and figure acceleration values of that events are presented, also. In the BHRC website are not displayed any location of these probable seismic foreshock events at that searching time. So, for verifying of those events, we not found them in the IrSC and IIEES catalogues.***

Table 1. Probable foreshock events in accelerometer catalogue of BHRC for the Fin earthquakes.

Fin Eq. Alarms?!	Probable foreshocks?! (Before the Eq. 1)								Double main-shocks		Aftershocks (After the Eq. 2)				
Day/H:M	13/ 20:23	13/ 20:30	13/ 20:39	13/ 20:40	13/ 21:28	13/ 22:02	13/ 23:11	14/ 00:11	14/ 12:07	14/ 12:08	14/ 12:18	15/ 09:45	15/ 13:36	15/ 13:36	15/ 20:19
Acceleration (cm/s/s)	12 (1)	12 (2)	14 (3)	36 (4)	15 (5)	74 (6)	39 (7)	16 (8)	369 (Eq. 1)	565 (Eq. 2)	27	23	3	3	117

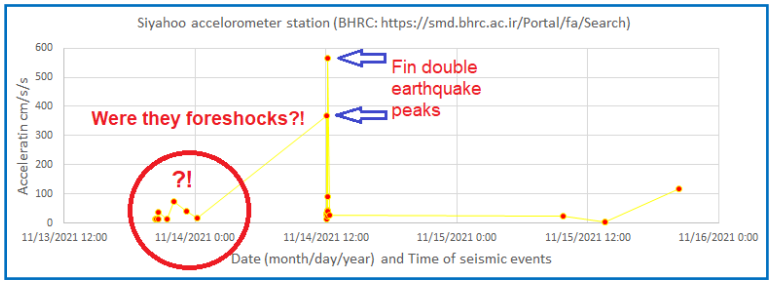

Figure 1. Probable foreshock events in accelerometer catalogue of BHRC for the Fin earthquakes.

For the b-value variations, we used the searched earthquakes in the IrSC and IIEES catalogues which reselect and rearrange by applying the criteria for more data reliability and confidence, then by using ZMAP software (Wiemer and Malone, 2001), we are processing the dataset selections. We tested and compared the data catalogues separately many times by temporal and spatial analyzing, clustering and de-clustering them. Herein, one of the temporal b-value variations analyzing results is shown in Fig. 2. Abnormalities from the normal, shown non sharp fits to the rises or falls of the seismicity as an expected indicator (right panel). Some b-value in accordance with the seismic up and down rate tracks, have high spatial uncertainties. The spatial b-value variations due to much earthquake location errors (sometimes up to 10 km and more) is associated with high uncertainties (left panel).

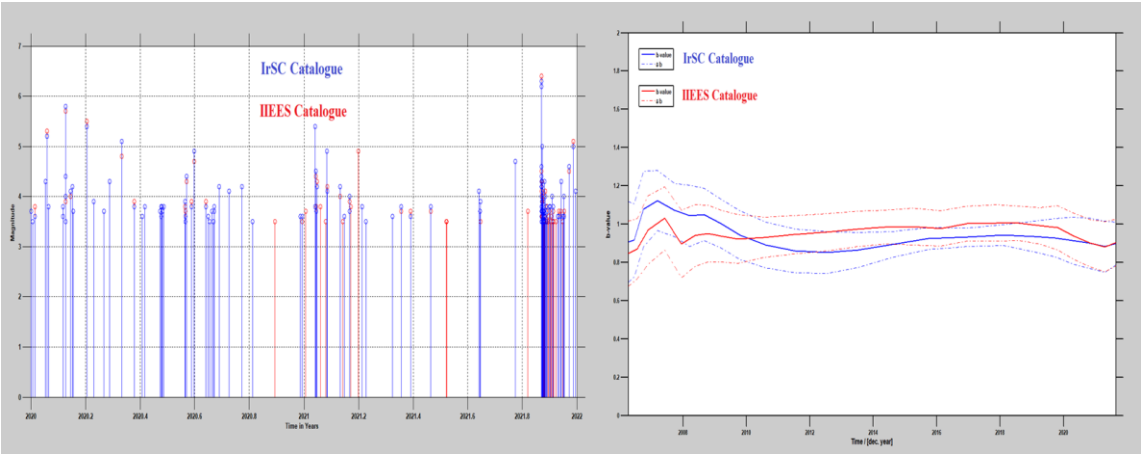

Figure 1. Temporal analysing of b-value variations of IrSC and IIEES catalogues for the Fin earthquakes. Seismic events, M≥3.5 in 2020 up to 2022 of the both catalogues (left), and their b-value fluctuations from 2006 up to 2022 time span (right). Note that the catalogue value differences is more than the b-value variation estimations by each of them individually.

For the VLF precursory, we used the VLF 18200 Hz band frequency data which have transmitted from the radio transmitter at India (VTX location, T) and after probable affected by the Fin seismic environment, then received by ELETTRONIKA receiver in the building No. 2 of IGUT/IrSC (Tehran-R) as indicted in Fig. 3 (left panel). The transmitter (T) and the receiver (R) are assumed to be at the focuses of an ellipsoid plane cross section of the Fresnel zone on the map. With these assumptions, we use of 130 days continuous the raw VLF data in the Research Center for Earthquake Precursors (RCEP) for analyzing a probable anomaly in the VLF signal amplitudes. The twice standard deviation criterion (2σ) for the average signal amplitudes (33.28 dB) is calculated 6.72 dB (40 for +2σ and 26.56 for -2σ), when we observed some anomalies much greater than the criterion about 19 (down) up to 50 (up) dB in amplitudes, respectively, from about 4 days before and 5 days after the main shocks (abstracted in the right panel of Fig. 3.

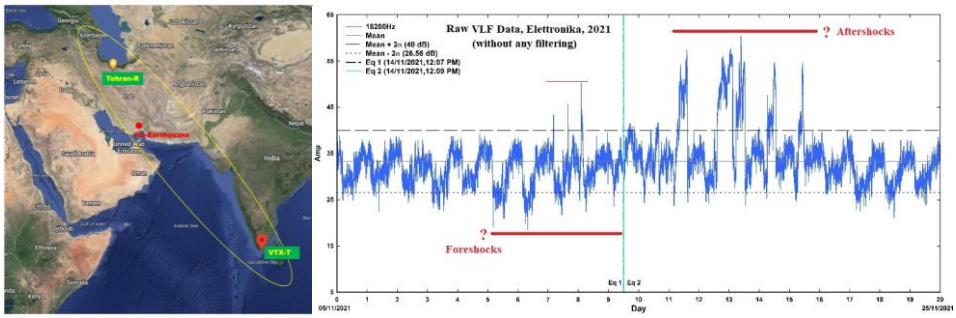

Figure 3. The transmitter-receiver (T-R) map and assumed ellipsoid cross section Fresnel zone plan for the VLF signals transmitted from RTX and received by ELETTRONIKA receiver in Tehran (left panel). The observed and analysed amplitude anomalies (compare to 2σ criterion) of the VLF signals before and after the Fin 14 November 2021, double-earthquakes.

CONCLUSIONS

The BHRC accelerometer stations are relatively proper numbers and distribution, the probable nearing it to an earthquake epicenter more than the seismological station (IrSC and IIEES), hence, the proceeded events the main-shocks must be reexamined. They should be verified and evaluated for manmade activities such as explosions, construction and/or the technical issues as well as their locations. So far, we did not have enough facilities to resolve this problem.

Some random temporal b-value variation fits to the seismic up-down tracks, do not have high certainties for reliable evaluating relation to the earthquakes, see Wang et al., 2016 as an important reference for the precursor time (T_P). The foreshocks and b-value analyzing are sensitive to the precise locations and the completeness of the used catalogues, whereas much location errors (sometimes more than 10 km) and obvious incompleteness, are in high uncertainty and risk. These deficiencies are affected the temporal b-value estimations, also.

Certain observed amplitude anomalies in the VLF signals from 2σ criterion in only using one receiver station is not enough to attribute the anomaly to the earthquakes. In follow the null hypothesis, we cannot ruled out it, while for verifying, have needed to be more and qualified data. The studied EP completely depend on the appropriate data which can be obtained by sufficient-proper instruments. It seems, not every earthquake alone creates all types of EP, or it is less possible to record, monitor and detect all of them. There are some facilitates and many restrictions simultaneously for the distributions of the receiver instruments on the ground and in space.

We hoped that with such reviews, necessity and importance of the data quality and improving of their acquisitions, be defined carefully and verified. There can be used of those types of reliable and high quality data in the pre-earthquake signals analyzing and or even high reliable forecasting or logic-scientific prediction, it valuable achievement if possible in the future. It is well-know that if many pre-earthquake signals with considerable care and confidence being examined, yet an early warning system and public awareness must be design and implement that can be use them in engineering lifelines.

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