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Study of Ionospheric Perturbations during Turkey – Central Earthquake of December 20, 2007

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ABSTRACT
Present paper deals with variation of foF2 (critical frequency) in F-region of ionosphere before seismic shock of Turkey-Central earthquake on December 20, 2007. A statistical analysis of variation in foF2 before earthquake has been presented. We analyzed foF2 data using bound method. The observed anomalous changes related to geomagnetic disturbances are filtered out (using Dst index). Assuming the remaining disturbances are due to earthquake which may be used as an earthquake precursor.

INTRODUCTION

Earthquake still occupy one of the first places in the list of natural disasters causing fatalities in human life. That is why the earthquake forecasting is, in spite of the difficult and entangled history, still on the top of the human agenda. The problem of earthquake forecasting is one of the major unsolved tasks of modern geophysics. Past two decade's events, the development and improvement of forecast methods have taken on as added urgency. Intensive research in the field of seismo - ionospheric effects together with traditional methods of geophysical forecasting is being conducted into developing various methods of earthquake forecasting. Out of all forecasting methods that have come up in the literature, the ionospheric precursor of earthquake is the latest.

Earthquake can excite atmospheric and ionospheric disturbances by dynamic coupling. Variations of the Earth's surface launch pressure waves in the neutral atmosphere that grow in amplitude by several orders of magnitude as they attain ionospheric heights. The first published observations of such disturbances were obtained after the great Alaskan earthquake in 1964 (Davies & Baker 1965).

The seismo - ionospheric coupling are very important for scientific community and it lists a large number of publications during last two decades (Pulinets et al., 2002; Plotkin 2003; Ruzhin et al., 2002; Stein & Okal 2005; Tronin 2002). There are number of evidences that electromagnetic phenomenon possibly associated with seismic activities have been greatly discussed in the publications (Hayakawa & Fujinawa 1994; Gokhberg, Morgounov & Pokhotelov 1995; Hayakawa 1999; Hayakawa et al., 2000; Hayakawa & Molchanov 2002). Scientists observed anomalies appearing in electron densities of the ionospheric F-region a few days before for some strong earthquakes (Pulinets, Legen'ka & Alekeseev, 1994; Pulinets, 1998; Liu et al., 2000; Liu et al., 2001) by examining the ionospheric plasma frequency (or electron density) recorded by a local ionosonde and found that the critical frequency of the F2 layer (foF2) significantly decreased few days prior to most of the earthquakes (M > 6) in the Taiwan area between 1994 – 1999 (Pulinets et al., 2000; Pulinets et al., 2005).

Ionosonde has been the most popular instrument probing the ionospheric electron density for more than several decades (Hunscucker 1991). Currently, there are more than 180 ionosondes available world wide and there are thousands of ground based receivers of the global positioning system (GPS) deployed to monitor the Earth's surface deformation rates using two frequencies f_1 = 1575.42 MHz and f_2 = 1275 MHz (Calais & Minster 1995). By analogy with seismology the wave movements were thought to be due to the ground movement before and after the earthquake. That is the reason why acoustic gravity wave and ionospheric coupling was the first seismo-ionospheric coupling mechanism. The after effects of seismic activity in the ionosphere were demonstrated by direct comparison of seismograms and records of Doppler shift registered by ionosonde (Yusf, Matsauka & Yamazaki 2001). Among many publications describing the electromagnetic and

ionospheric phenomenon associated with earthquake. Every earthquake has its individual properties, so the observed variation should not be completely identical. The first publications dealing with ionospheric parameters variation as seismic precursors were recorded by (Antselevich 1971; Tsai & Liu 2004) which were related to the study of the variation of foE parameter before the Tashkent earthquake was discussed. Consequently, case study papers started to appear regularly. These were based mainly on ground based –ionosonde data; however, the first paper using satellite data began to appear as well (Gokhberg et al., 1984).

METHOD AND ANALYSIS

Current ionosonde techniques are some of the most efficient means of searching for seismo - ionospheric precursors. The data of foF2 obtained from NOAA Space Environment Center and data of Dst index obtained from WDC Kyoto Japan. To identify abnormal signals, we compute the median $\overline{X}$ for the period of one month data of foF2 and associated inter-quartile range (IQR) to construct the upper bound $\overline{X}$ + IQR and lower bound $\overline{X}$ -IQR (Liu et al., 2004). If an observed foF2 falls out of either the associated lower or upper bound, then we estimate with a confidence level of about 90-95% that a lower or upper abnormal signal is detected. For the study of earthquake precursor we calculate the median value of the data and then calculate the standard deviation of time series data. The upper bound and lower bound is calculated by using the following formula:

Upper bound (UB) = $\overline{X}$ + IQR
Lower bound (LB) = $\overline{X}$ - IQR

Where $\overline{X}$ is the median value of foF2 time series data and IQR is the inter quartile range. To study the day-to-day variation in hourly foF2 values a deviation analysis method is used to detect percentage deviation which increases and decreases from upper and lower bound respectively. Percentage deviation has been calculated with the help of following equations:

% Deviation Increase = [($\overline{X}$ -UB)/UB ×100]
% Deviation Decrease = [(LB − $\overline{X}$)/LB × 100]

We have observed anomalous variation of ionospheric foF2 which seems to be associated with earthquake before and after its occurrence by analyzing foF2 data. Anomalous variation of foF2 is taken to be different from the observed hour-to-hour and day-to-day variability. We know that perturbation in foF2 value is also related to geomagnetic condition therefore to remove the geomagnetic effect from foF2 variation, the observed variation in foF2 values are filtered by setting a threshold value ±15nT for Dst index. To precise observation of seismic–anomaly, the observed anomalous variation drawn at logarithmic scale also.

CHARACTERISTICS OF EARTHQUAKE

Characteristics of earthquake of Turkey – Central described in Table (1), with time of earthquake (UT), intensity, focal depth, ionosonde station, longitude / latitude and distance from the epicenter.

RESULTS

In our study ionospheric variations were examined before Turkey-Central earthquake of December 20, 2007. For this event we have considered foF2 data observed from Athens station for the entire period of December 2007 and analyzed using the equation of upper and lower bound method. Results plotted are shown in Fig (1) to Fig (6) and Table (2) gives the earthquake precursory result.

For better understanding of seismo-ionospheric coupling, the observed foF2 variations were examined before and after main shock of earthquake. Fig (1) shows variation of foF2. Fig (2) shows the logarithmic variation of foF2.

Fig (3) shows the percentage deviation of foF2 while solar and geomagnetic disturbances are not filtered whereas Fig (4) shows the logarithmic percentage deviation of Fig (3), which shows precise observation of abnormal ionospheric variations. Fig

Table 1. Characteristics of Turkey-Central earthquake.

S.N.	Location	Date of earthquake	Time of earthquake (UT)	Intensity	Focal Depth in km	Ionosonde Station	Location of Station	Distance from Epicenter
1	Turkey -Central 39^0N and 33^0E	20-12-2007	09:48:29	5.7	10 km	Athens	38^0N & 24^0E	791 km

(5) shows the percentage deviation of foF2 while solar and geomagnetic disturbances are filtered out by threshold value ±15nT of Dst index. This figure shows that abnormal enhancement in foF2 from the upper bound of IQR is observed. Fig (6) shows the logarithmic variation of Fig (5). It is clear from Fig (6) that an anomaly presents before eight days from the main shock of earthquake. In these figures 'E' marks the time of occurrence of main shock of earthquake and 'P' marks the precursory phenomena.

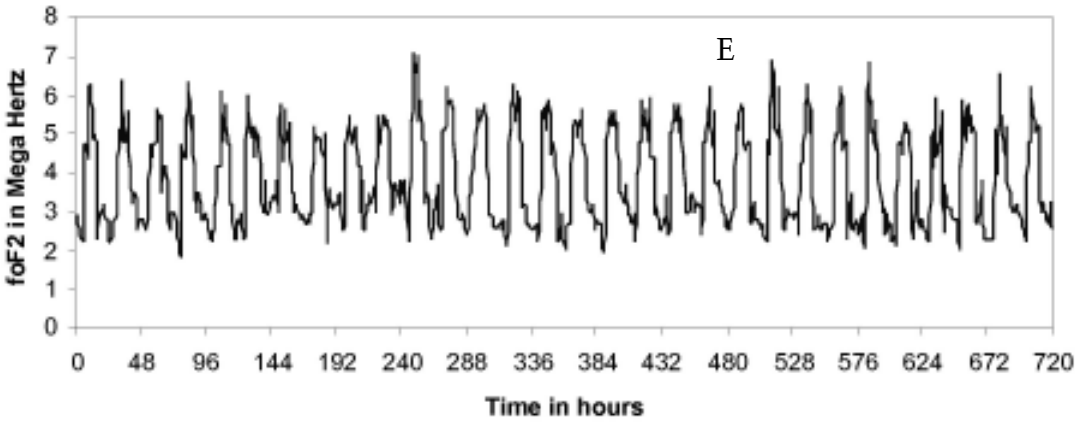

Figure 1. Variation of foF2 [date of earthquake December 20,2007 over Athens station].

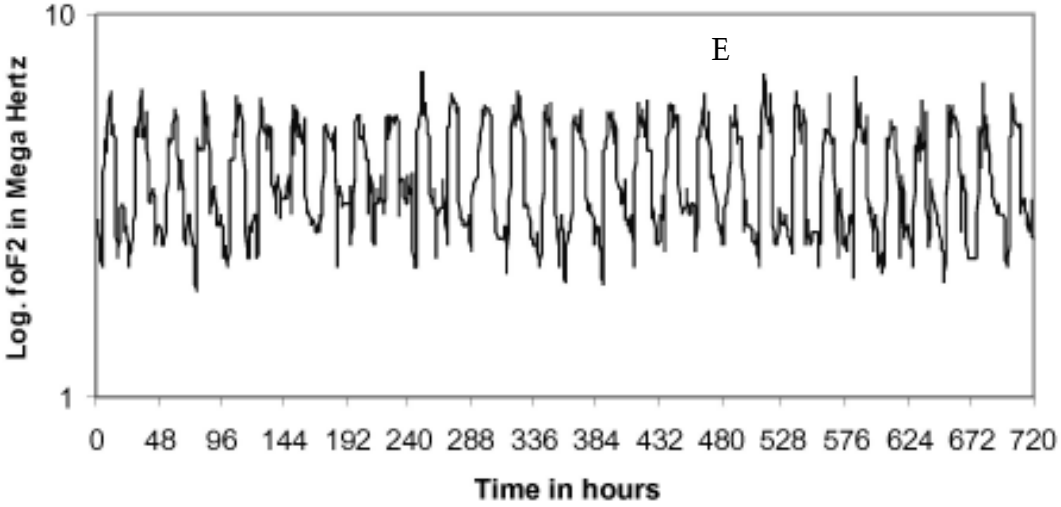

Figure 2. Logarithmic variation of foF2.

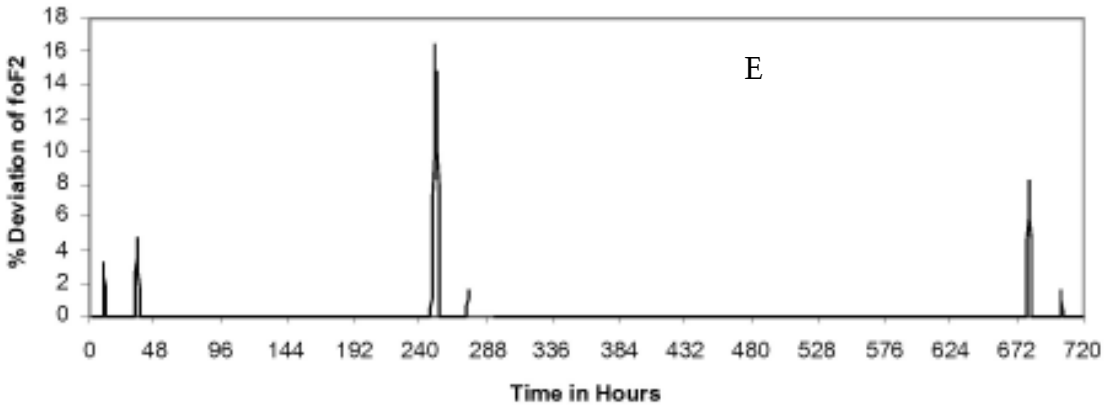

Figure 3. Percentage deviation of foF2 (without filter).

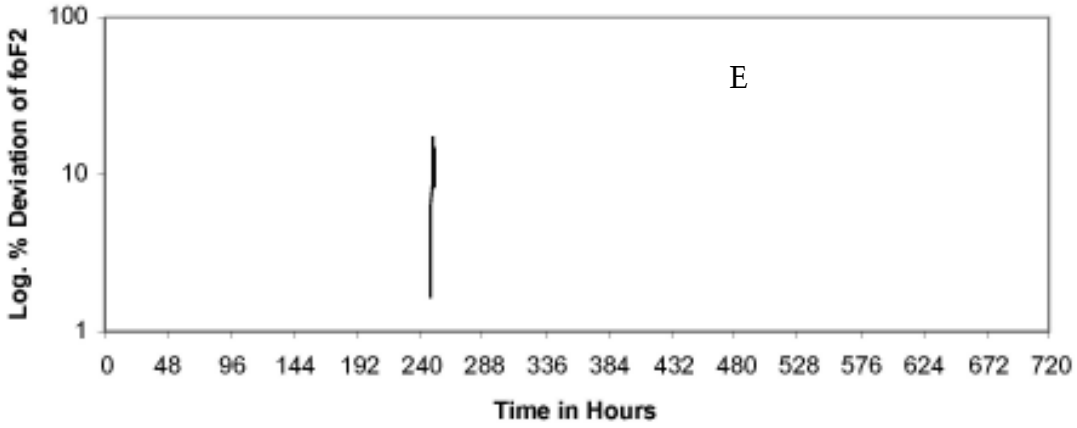

Figure 4. Logarithmic percentage deviation of foF2 (without filter).

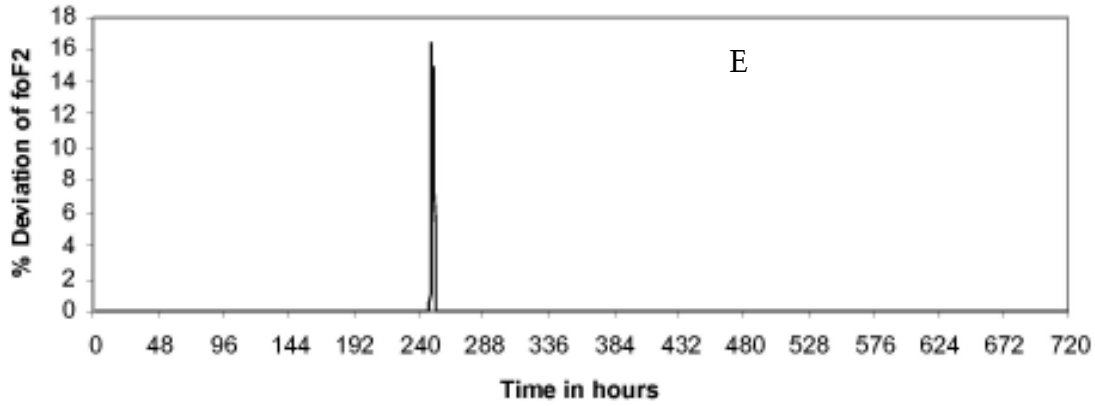

Figure 5. Percentage deviation of foF2 (with filter).

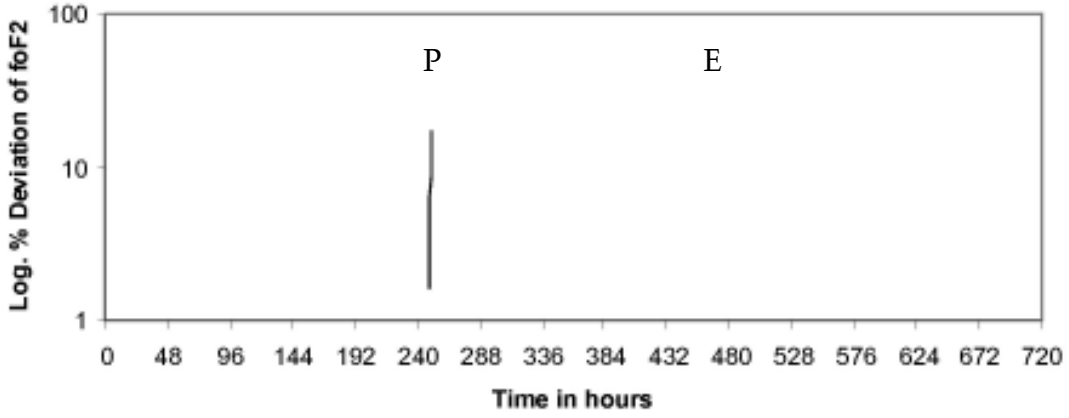

Figure 6. Logarithmic percentage deviation of foF2 (with filter).

Table 2. Earthquake precursory result.

S.N.	Location	Date of earthquake	Time of earthquake (UT)	Intensity	Focal Depth in km	Ionosonde Station	Location of Station	Precursor Observed
1	Turkey-Central 39^0N and 33^0E	20-12-2007	09:48:29	5.7	10 km	Athens	38^0N & 24^0 E	Before 8 days from earthquake

DISCUSSION AND CONCLUSIONS

The results described in the above section showed the significant ionospheric perturbations over the Athens station several days before and after the main shock of earthquake occurred in Turkey-Central. These ionospheric disturbances are related to the action of upward propagating electric field which is produced due to tectonic movements which enable electric charge to appear at the surface of the Earth and modify the current in atmosphere-ionosphere system. The Earth's ionosphere is strongly dependent on solar and magnetic disturbances. In present analysis, all ionospheric disturbances related to solar and geomagnetic disturbances are first separated out. According to seismo – ionospheric responses arising during the earthquake preparation stage, it is known that the modification of the anomaly associated with seismic activity has various characteristics and is observed eight days before the earthquake. In the course of the preparatory stage of earthquake, there was a penetration of abnormal electric field of seismogenic origin into the ionospheric heights which strengthens or weakens the variation of foF2 (Pulinets & Boyarchuk 2004). It moderates the $\mathbf{E} \times \mathbf{B}$ drift process and causes subsequent spatial distribution of electron concentration.

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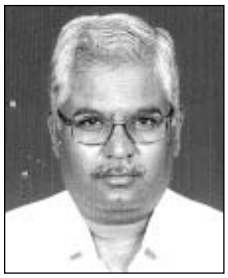

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