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Investigation of Seismic Precursor Using Correlation Analysis Technique

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Abstract

In this article we studied the variation of Maximum Electron Density (NmF2) concentration in the ionosphere calculated by earth positioning ionosonde around the time of strong seismic shock. We used NmF2 data of two stations Athens and Sanvito. We calculate Karl –Pearson coefficient of correlation. Results of the study showed that Karl- Pearson Coefficient get maximum disorder before two days from the seismic shock. It may be due to the generation of seismic wave during earthquake, which propagate upward and perturb the F-region ionosphere. Results may be beneficial in seismic precursor study.

Keywords: NmF2, F-region, seismic precursor, earthquake.

Introduction

Ionospheric disturbances by seismic occurrence, like volcanoes, tsunamis and earthquake have been calculated before 1965. Measurements done by the earth positioning instrument, show a change in TEC (Total Electron Content), foF2 (Critical Frequency of F2 layer) parameter, prior and later than the seismic event. Pulinets and Legen'ka[1] works on earthquake precursor and report that earthquake related ionospheric variations depend on time, prior the beginning of the earthquake activity. Perturbations in the ionosphere related to seismicity are appeared, some days prior the main seismic event, but on this time the perturbed area does not exist on the main seismic point but its appearance appeared at the near - by point. The perturbations in the ionosphere related to seismicity may propagate towards the magnetic field lines of the hemisphere. By the help of ground based ionospheric sounders the perturbations in foF2 parameter and TEC (Total Electron Content) ionospheric parameters were recorded. But satellite based techniques of measurements for Total Electron Content (TEC) parameter also be used. Total electron content (TEC) is the integration of the concentration of electrons from the earth and the satellite. Thus TEC (Total Electron Content) parameter is the measure of electron concentration of F- region of ionosphere.This method has been used to observed anomalous variations due to seismic phenomenon by Calais and Minster[2] and Liu J.Y.[3]. Molchanov et al.[4] have used a technique based on statics with total electron content data from TOPEX – POSEIDON to detect regression or correlations related to ionospheric vaiations and earthquake. Liu et al.[5] also used a statistical technique to calculate the ionospheric TEC (Total Electron Content) from digital data observed by a satellite based network (GPS) Global positioning system in Tiawan. It based on the network data the latitude time – TEC plots are constructed and showed that 1-4 days prior the three earthquakes on sets, TEC values decreases and anomaly crusts move toward the equator. Further, the simultaneously deduced overhead TEC and the foF2 observed at Chung – Li during the three earthquakes are compared and examined. In a publication of Liu et al.[6], a statistical analysis of TEC anomalies has been performed before strong earthquake. With the help of top sound sounder installed onboard the intercosmos-19 satellite, strong variations in the vertical structure of the ionosphere over the region of preparing earthquake was discovered by Pulinets et al.[7] and Pulinets et al.[8]. These include variations of electron density in F- layer maximum manifested in critical frequency variations. The density height distribution variations imply a change of the positive ion composition within the F-layer of the ionosphere. The ionosphere rises over the seismo-active region forming a dome of density depletion. These variations are most intensive for specific intervals of local time i.e. before the sun rise and in afternoon hours. In this paper we studied the data of maximum electron density in F-region of the ionosphere.

Methodology

The ionospheric variability given by NmF2 parameter (Maximum Electron Density of F2 layer) (NmF2) is analyzed for seismic effect of the earthquake occurred on January 08, 2006. This technique we applied to correlate the data of the seismic related station to neighbour station to reveal the earthquake related variations. In this study we measure the maximum electron density, of two different ionospheric stations. In this technique we use an idea of earthquake preparation zone and correlation radius. We used the concept of earthquake preparation area to calculate the associated seismic effect. The assumption was taken that ionospheric variability will be appeared under the boundary of seismic zone. We used formula 1 to determine the radius of seismic preparatory area used by previous workers [9,10]:

$$R = 10^{.43M} \quad (1)$$

In the above equation 'R' indicates the radius of seismic preparatory area, and 'M'denotes the magnitude of seismic event.

There are two measuring locations, first is (Sensor point), located under the boundary of seismic preparatory area, and other is (Control point) located out side of the boundary of seismic preparatory area. These are shown in following figure:

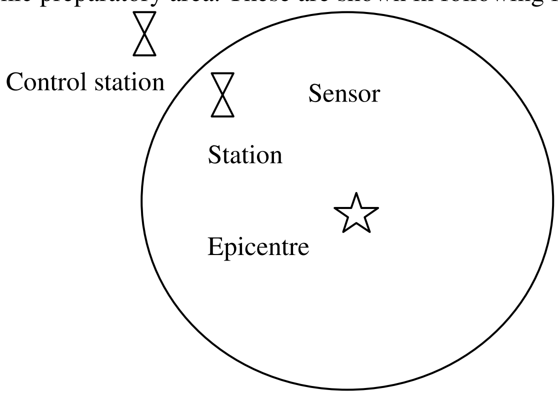

Figure-1
Radius

Above figure shows the radius of, seismic preparatory area, epicentre, and sensor station and control station. Here it is not mandatory to put control station outside of the boundary of seismic preparatory area but generally, we put it so far from the point of main seismic shock.We calculate the daily cross – correlation coefficient by the following formula

$$C = [\Sigma \{(NmF2_1 - <NmF2_1>) * (NmF2_2 - <NmF2_2>)\} / (k\, \sigma_1\, \sigma_2)] \quad (2)$$

In the above equation indices 1 is for 'Sensor Point Ionosonde' and indices 2 is for 'Control Point Ionosonde', and NmF2 the parameter of measurement of the peak electron density in the F2 layer, analyzed by the time series data of foF2 parameter, these values are calculated from ionosonde measurements k = 24, or k =96 or k=144 depends on the values recorded per day. If the recorded values are 24, i.e. the data is hourly interval than we used k=24, and if the measurement is made by 15 minutes of interval than we use the value of k is 96. Average value of peak electron density of F2 region <NmF2> and S.D. (Standard Deviation) σ are calculated by the following equations:

$$< NmF2 > = [\Sigma \{(NmF2)_i/k\}] \quad (3)$$

$$\sigma^2 = \Sigma\, [(NmF2)_I - <NmF2>]^2/k \quad (4)$$

Where <NmF2> is the mean value of peak electron density of F2 region and σ is the index of standard deviation. We applied this method on the series of earthquakes in the different areas of earth. We used the data of two stations Athens (38^0 N and 24^0 E) and San-Vito (40^0 N and 17^0 E). In these two, Athens station is located inside of the boundary of earthquake preparatory area and other station Sanvito is located outer side of the boundary. Cross- Correlation study for these stations is shown in figure 6.

Data

In this study data of NmF2 were obtained from NOAA space environment centre. We used ionospheric data, base of 2005 to 2006. We used SWPC Anonymous FTS for downloading ionospheric data base. These ionospheric data base was prepared by the U.S. Department of Commerce NOAA, space environment centre. For earthquake data characteristics we used NGDC acquiesces, processes which disseminates the data in many usable format. We used the global significant earthquake data base of January 2006. For earthquake location figures we used Natural Hazards interactive viewer, site haz.info@noaa.gov.

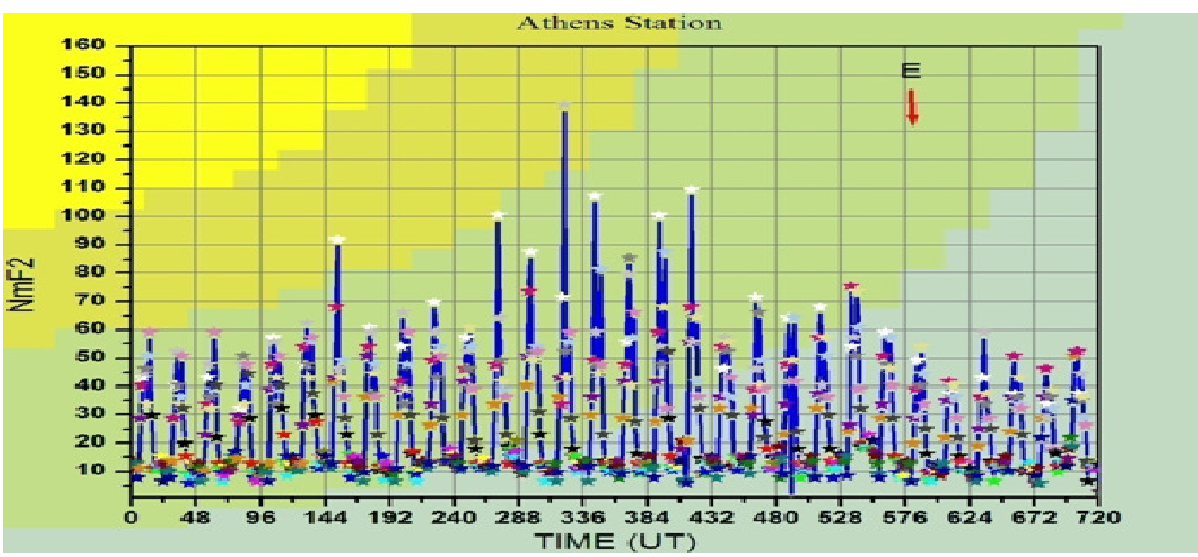

Figure-2
Variation of NmF2 for earthquake of January 08, 2006

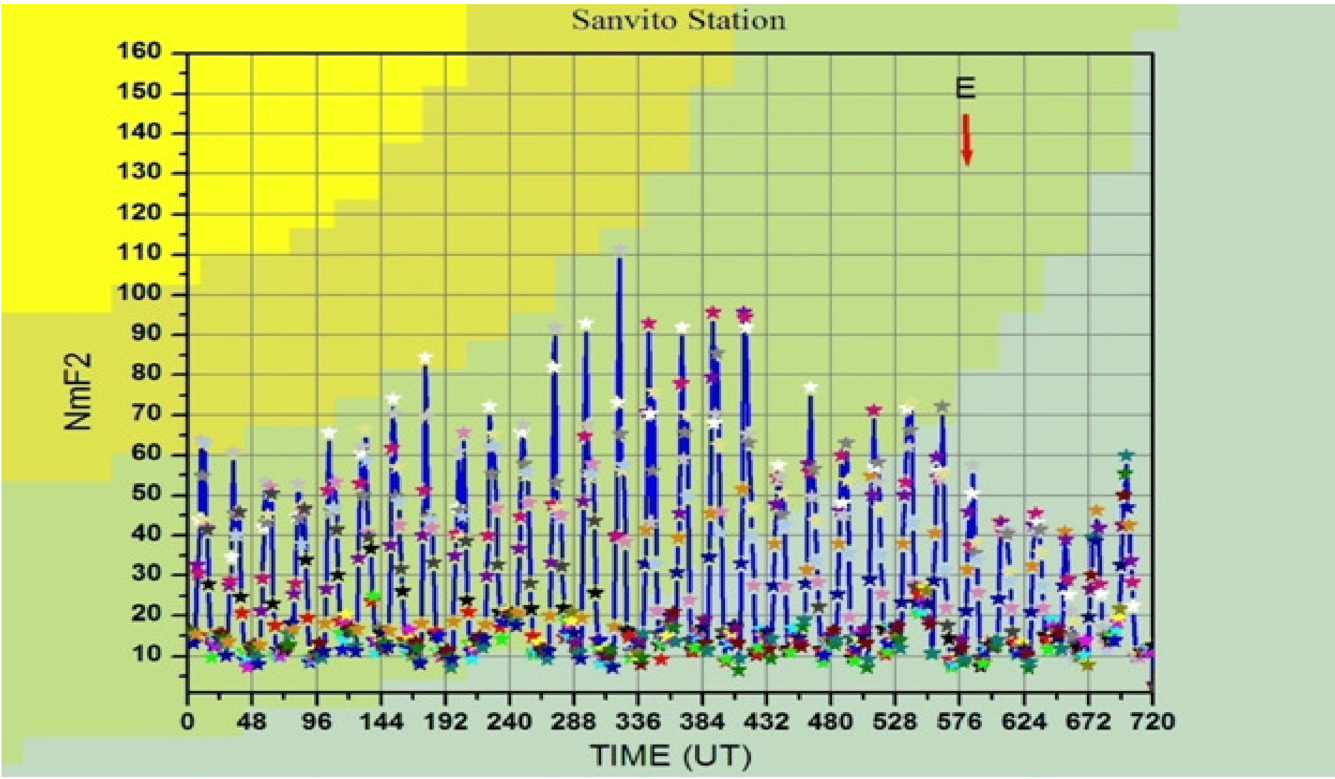

Figure-3
Variation of NmF2 for earthquake of January 08, 2006

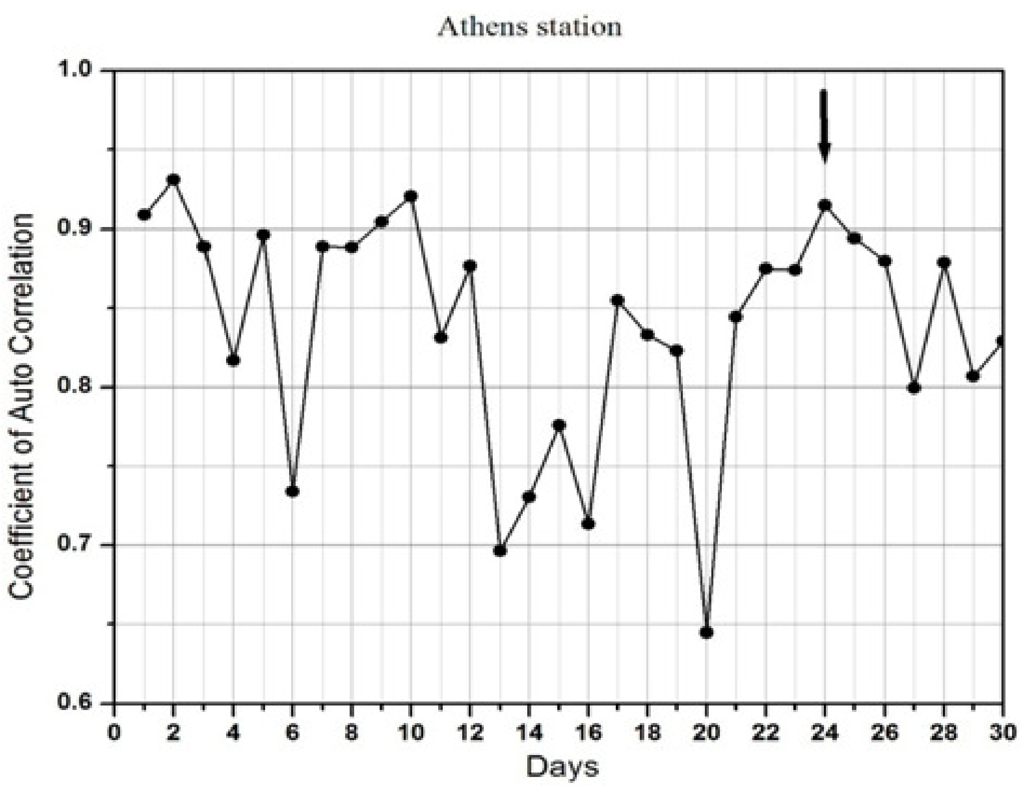

Figure-4
Variation Auto correlation coefficient for earthquake of January 08, 2006

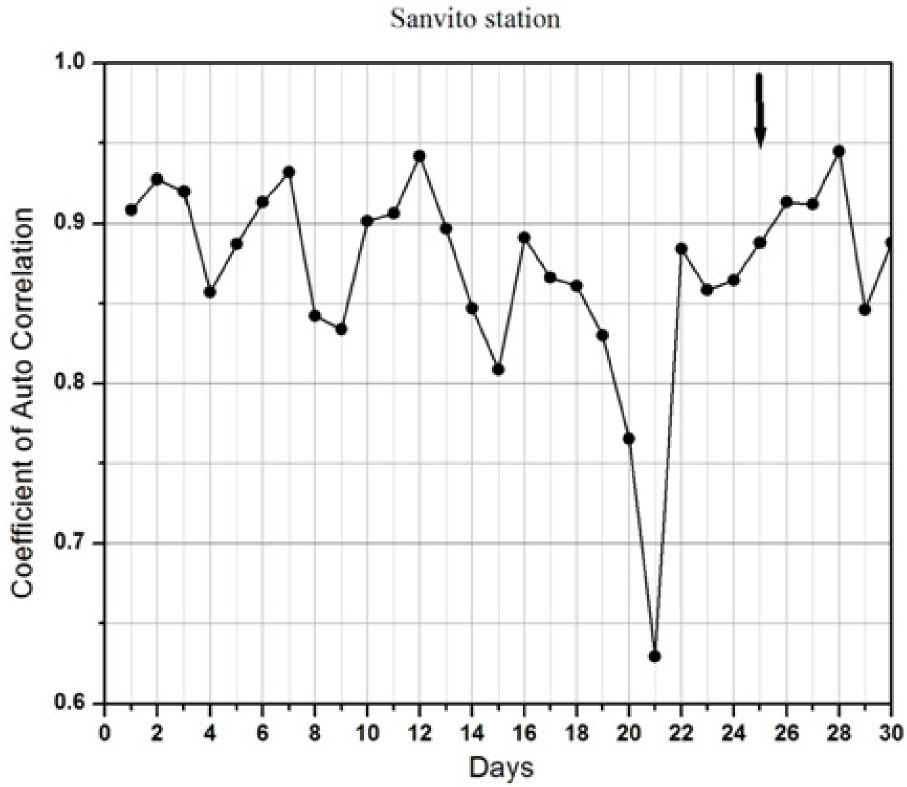

Figure-5
Variation Auto correlation coefficient for earthquake of January 08, 2006

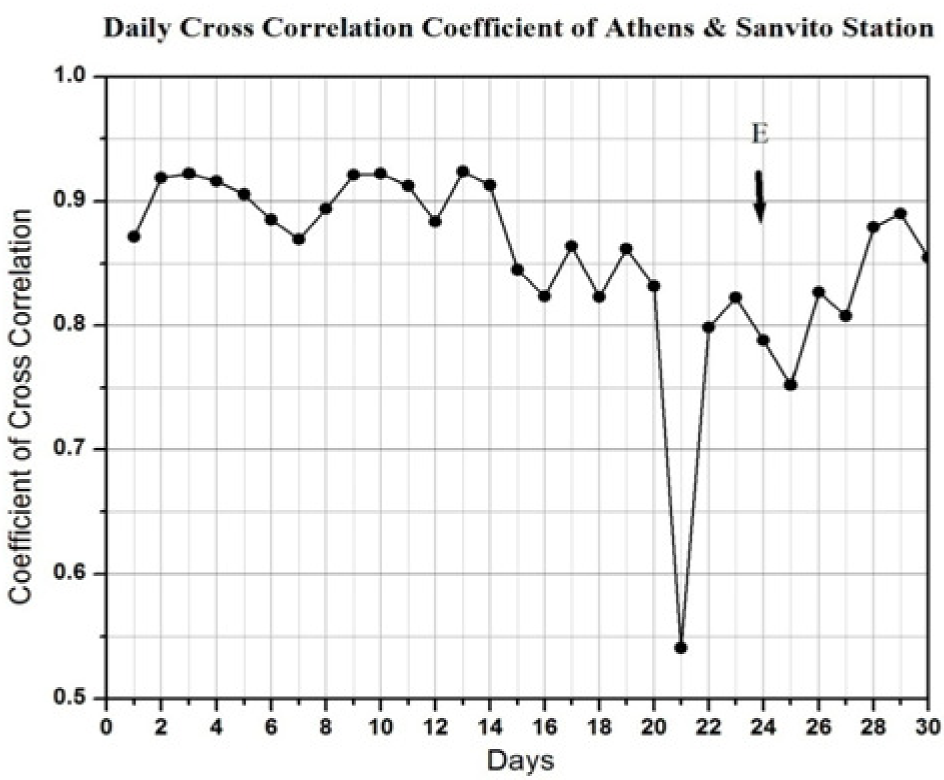

Figure-6
Variation cross correlation coefficient for earthquake of January 08, 2006

The epicentre of this earthquake was located at 36^{0}N and 23^{0}E. The magnitude of the event was 6.2 on Richter scale and focal depth 66 kms. The distance from Athens station was 239 km and distance from Sanvioto station 689 kms. Using equation 1 , the earthquake preparation area is calculated as 463 kms, and therefore Athens is expected to pick up the ionospheric precursors It's clear from figure that Athens is the nearby ionosonde station. Athens is located inside of the boundary of seismic area. Figure 3 shows the variation of NmF2 for Athens station. Figure 4 shows NmF2 variation for San-vioto station. Figure 5 and 6 shows auto correlation study for Athens and Sanvioto station respectively. The cross correlation study of NmF2 parameter for Athens and Sanvioto station is shown in figure 6. As shown the cross correlation coefficient drops 3 days prior to earthquake on 5 January 2011. The drop in daily cross correlation coefficient may be used as precursor.

Conclusion

Ionospheric perturbation based seismic precursor have significant character in earthquake prediction study. In our work we used cross correlation method. We calculate Karl-Pearson coefficient of correlation. This method is reliable and beneficial because effect of geomagnetic storm filtered by cancellation of both stations. Hence remaining perturbations may be considered by other activity such as seismic or volcanic. But ionosonde of observatory station is located inside of the boundary of seismic area, so it is confirm that the remaining perturbations are related to seismic activity. Hence this study may be beneficial in earthquake prediction. This method of prediction is also important because it is cheaper than other satellite based prediction techniques. There are some limitations also in this method. First is to select the earthquake preparation area, and position of sensor station and second is to choose the location of control station. Control station must be outside of earthquake preparation zone, but not so far and located on same latitude. Hence in the same latitude control station selection is a difficult task. Whole study is carried out the scientific and significant information of ionospheric perturbation due to earthquake. We conclude here that at the beginning of seismic shock, energy released from the rock. This energy propagate upward and perturbed the 'F' region maximum electron density NmF2 parameter.

Acknowledgement

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