IONOSPHERIC ANOMALIES DETECTED OF SHIRAZ EARTHQUAKE USING WAVELET TRANSFORM

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ABSTRACT

Prior to major earthquakes many variations in the environment have been occurred.These changes are observed at the land surface,in water,in the air and in the ionosphere.On 19 April 2013 at 02:11 LT(UTC=LT-4:30),an earthquake happened in SW Iran,SHIRAZ region with a magnitude of M_w=5.0.

This paper analyses the ionospheric total electron content(TEC) obtained by GPS station of SHIRAZ and variations in TEC during two months(March to April) using BERNESE Software.The ionospheric anomalies before and after earthquakes has been able to represent that relationships between Seismics and ionospheric disturbances.In this paper,The geomagnetic and solar activities in detecting earthquake-associated TEC anomalies have been considered(Kp<2.5,D_{st}>-20 nt,Ap<25 and F10.7<130).*The research shows* variations of geomagnetic and solar indices during elected period(1 March to 31 April 2013).Then,the Continues Wavelet Transform(CWT) is used to detect and diagnose the ionospheric anomalies related to seismic activities. In this paper,detected anomalies during several days before earthquake with considering geomagnetic activities,might be related to approaching earthquake.*high levels* of the geomagnetic and solar activities are seen the results,therefore there are several peaks before the earthquake .

INTRODUCTION

The crustal movement perpendicular during an earthquake causes the displacement of the atmosphere on the Earth's surface and provides a remarkable template temporal anomalies past earthquakes (Liu et al., 2004; Pulinets and Boyarchuk, 2004; Ouzounov et al., 2007; Inan et al., 2008; Kon et al., 2011).The

character of the ionosphere varies greatly in space and time (sunspot cycle, seasonal, and diurnal), with geographical location (polar, aurora zones, mid-latitudes and equatorial regions), and with definitive solar-related ionospheric perturbations.Total electron content(TEC) is one of the parameters of the ionosphere that generates the most effects in many radio applications. TEC is described by the integral of electron density in a 1 m^2 column along the line of sight of the receiver relative to the satellite. TEC is a key parameter in the detection of ionospheric anomalies before strong earthquakes.TEC is measured in units of 10^{16} electrons/m^2 = 1 TEC unit (TECU) (Abdullah, 2009 and Ya'acob,2010). The substantival range is 10^{16} to 10^{19} with minima and maxima happening at midnight and mid afternoon.

In this paper, the TEC is observed at the F layer because this region has the extreme variability of free electrons, causing the greatest effect on anomalies detected before great earthquake.Liu et al. (2009) showed strong positive and negative ionospheric anomalies within 3 and 6 days before the 12 May 2008 Wenchuan earthquake.Sharma et al. (2010) detected the abnormal variations in the ionospheric total electron content (TEC) and foF2 within a few days before the main shock of the three great earthquakes (M > 6) in China.Yao et al. (2012) analyzed pre-earthquake ionospheric anomalies during the 2011 Mw = 9.0 Japan earthquake period, using data from GPS and ionosonde stations near the epicentre.

TEC DATA

GPS is a satellite based navigation radio system which is used to investigate the position and time in space and on the Earth. The GPS satellites are orbiting the Earth, at altitudes of about 20,200 km, communicate signals that propagate through the ionosphere that exists at about 60 –1500 km above the Earth's surface.Total electron content(TEC) is one of the parameters of the ionosphere that generates the most effects in many radio applications.In this work,Bernese GPS Software (BGS) was used to map the TEC of ionospheric with PPP technique parameterizations and computed based on the BGS Software and the output is in standard IONEX.Another technique based on wavelet transform is used.

GPSEST is the program that able to produce TEC maps in IONEX (Schaer et al., 1998,Ya'acob, 2010).GPSEST program is used to model the ionosphere. A MSLM was used for plotting the TEC, approximated by a spherical layer with infinitesimal thickness assuming that all free electrons are *focused* in altitude, H, above the spherical Earth. The altitude H of this *desired layer* is set to 450 km.

GEOMAGNETIC DATA

The geomagnetic storms and disturbances can change the ability of the ionosphere to reflect signals. There are two indices that are used to determine the level of geomagnetic activity: the Ap index and the Kp index. These give indications of the intensity of the magnetic oscillations and the *ionospheric perturbations*. The first of the two indices used to measure geomagnetic activity is the kp index. At three hourly intervals beginning at 00:00 UTC each day.The kp index is a "quasi logarithmic" number and can't demonstrate a longer term view of the state of the Earth's magnetic field. The Ap *index* provides a *daily average* level for geomagnetic activity.

ANOMALY DETECTION USING WAVELET TRANSFORMATION

Wavelet transform is a modern mathematical method used for nonlinear data analysis and has been one of the most effective techniques for analyzing the nonstationary signals (Mallat, 2008;Akhoondzadeh,2012;Akhoondzadeh,2013).In the wavelet applications, the continuous wavelet transform (CWT) can be detected ionospheric anomalies. In this paper, the wavelet transformation has been applied on the TEC time series of earthquake and can be calculated using the following equation:

$$X_w(a,b) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} x(t)\, \psi^* \left(\frac{t-b}{a} \right) dt \qquad (1)$$

Where, a is the scaling factor, b is the location parameter, ψ^* is the complex conjugate of continuous wavelet function,and $x(t)$ is the TEC time series of earthquake.

RESULTS AND DISCUSSION

The implementation of the above method has been performed on the Shiraz earthquake. The Shiraz earthquake happened during high solar activity in the 24th solar cycle. On 19 April 2013 at 02:11 LT(UTC=LT-4:30),an earthquake happened in SW Iran,SHIRAZ region with a magnitude of M_w=5.0.Figure 1 show respectively the variations of TEC, Kp, Dst ,F10.7 ,Ap and sunspot indices of time interval between 1st March to 31 April 2013.

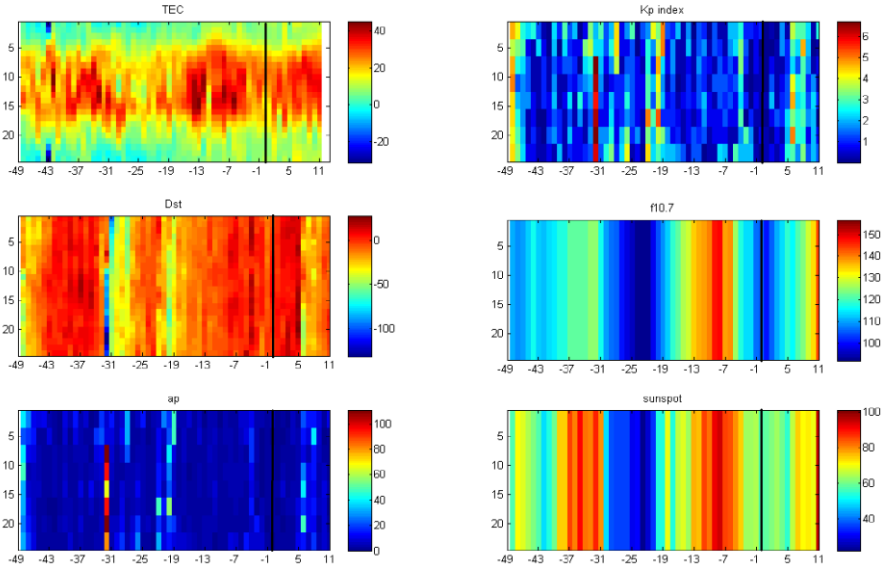

Figure 1. a ,b,c,d,e,f show respectively the variations of TEC, Kp, Dst ,F10.7 ,Ap and sunspot indices of time interval between 1st March to 31 April 2013.

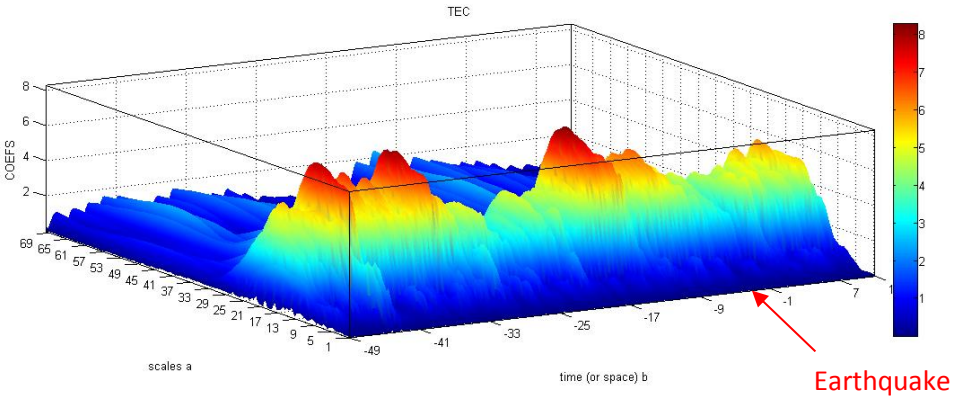

Figure 2. The result of CWT for ionospheric TEC (SHIRAZ Earthquake)

In this study,The geomagnetic and solar activities in detecting earthquake-associated TEC anomalies have been considered($Kp<2.5$,$D_{st}>-20$ nt,$Ap<25$ and $F10.7<130$).Under *quiet geomagnetic conditions, TEC variations* are considered. Then,the Continues Wavelet Transform(CWT) is used to detect and diagnose the ionospheric anomalies related to seismic activities.

Figure 2 shows The result of CWT for Shiraz *Earthquake Ionospheric* Anomalies Monitored by GPS *TEC*.Possible ionospheric TEC anomalies *approximately before* the *earthquake* are detected and diagnosed by CWT. Enhancement ionospheric TEC anomalies happened 7-14 days before the Shiraz earthquake, right over the epicenter have been discovered . The abnormal disturbances of ionospheric TEC *occurred on* March 17 (high geomagnetic and solar activities) and *occurred near time earthquake.*

CONCLUSIONS

The IONEX data have been produced from the BGS software with PPP program.This proved that PPP technique can be used to produced TEC map over single receiver station(SHRZ GPS station).In this paper,the capability of the wavelet transform method to detect the ionospheric TEC perturbations before the April 19, 2013 Shiraz earthquake are demonstrated.The high geomagnetic and solar activities are affected in ionospheric TEC and ionospheric perturbations caused by *These activities*.

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