Geodesy and Geodynamics 2014,5(2):54-60

http://www.jgg09.com
Doi:10.3724/SP.J.1246.2014.02054

# Analysis of ionospheric anomaly preceding the *M*w7.3 Yutian earthquake

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**Abstract**: On February 12, 2014, a large *M*w7.3 earthquake occurred in Yutian of Xijiang Province, China. We processed the global ionosphere maps provided by CODE (the Center for Orbit Determination in Europe) and the foF2 (the critical frequency of F2-layer) data of Chongqing ionosonde station to analyze the pre-earthquake ionospheric anomalies. Solar activities and magnetic storm were checked by the sliding inter quartile range method to remove their effects on the ionosphere. A positive ionospheric anomaly with the large amplitude of 20 TECU was observed near the epicenter on February 3 (10th day before the earthquake). In addition, the foF2 at Chongqing station had an unusual increase of more than 40% on the day, which was consistent with the TEC (Total Electron Content) anomaly. The global disturbance represents that the peak of TEC anomaly didn't coincide with the vertical projection of epicenter. The TEC anomalous area was closer to the equator, and it mainly occurred from local time 16:00 to 20:00. An enhancement of TEC with the small amplitude also appeared in the magnetically conjugated region.

**Key words**: Yutian earthquake; ionosphere; anomaly; TEC; foF2

## 1 Introduction

Earthquakes are one of the most destructive natural disasters, which can bring the tremendous damages to human life and property safety. Seismologists make great efforts to improve the accuracy of earthquake prediction. The results[1,2] show that earthquakes can not only affect the surface configuration, but also spread to ionosphere to make the total electron content (TEC) unusual[3-15]. Therefore, the pre-earthquake ionospheric anomaly is one of hot researches recently.

February 12, 2014, a large *M*w7.3 earthquake occurred in Hetian, Xijiang, whose epicenter was located in Yutian (82.5°E, 36.1°N) with the hypocentral depth of about 12 km. This is a strike-slip earthquake. We use the global ionosphere maps (GIM) provided by CODE, and optimize the reasonable background values according to ionosphere periods after eliminating ionospheric anomalies that caused by solar activities and magnetic storms in the paper. Then the pre-earthquake ionospheric disturbances over the seismic zone are analyzed in detail.

Received: 2014-03-10; Accepted: 2014-04-25

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This study is supported by the National Basic Research Program of China (2013CB733302), the National Natural Science Foundation of China (41374009), the Public Benefit Scientific Research Project of China (201412001), and the Natural Science Foundation of Shandong Province, China (ZR2013DM009).

## 2 Data and detection method of abnormal information

### 2.1 Data

The pre-earthquake disturbances usually affect the TEC, the critical frequency of F2-layer (foF2), the critical frequency of sporadic E-layer and so on[16]. TEC and foF2 will be mainly studied in the paper. TEC data are extracted from GIM provided by CODE (ftp://ftp.unibe.ch/aiub). Now a large number of IGS stations are evenly distributed all over the world, whose data are used to estimate TECs suitable for investigating ionospheric anomalies over a wide geographic range after the interpolation and the smoothness. CODE usually estimates TECs from the dual-frequency code and phase data of IGS stations[17]. Now the time resolution of CODE global ionosphere maps is two hours with the spatial resolution of 5° in longitude and 2.5° in latitude.

The F layer is relatively stable, and foF2 is one of the most important parameters of ionosphere. So foF2 is also the key point to analyze the earthquake-ionosphere effect[3]. The Chongqing ionosonde station is the nearest station to the epicenter region, locating in the southeast of Yutian. Previous researches have suggested that ionospheric anomalies caused by earthquake usually appeared in the equatorial side of epicenter[1]. The foF2 data of Chongqing station are provided by the Space Weather Prediction Center (SWPC) (http://www.swpc.noaa.gov/Data/index.html).

In order to eliminate the ionospheric anomalies that may be caused by the solar and magnetic activities, we possess four parameters to study the pre-earthquake solar-terrestrial environment, which are the sunspot number (SSN), the 10.7 cm solar flux (F10.7), the equatorial geomagnetic activity index (*Dst*), the global geomagnetic activity index (*Kp*), respectively. SSN data are provided by the Solar Influences Data Analysis Center (SIDC). It is the major target which represents solar activity and has been observed for more than 300 years. F10.7 data express the microwave flux density of 10.7-centimeter wavelength, and also a significant parameter to show solar activity level. The range of F10.7 is usually from 60 to 300 SFU. Dst index and Kp index are provided by the World Data Center for Geomagnetism, Kyoto (http://wdc.kugi.kyoto-u.ac.jp/dstae/index.html). Dst index is calculated every hour, which usually indicates the geomagnetic activity level of low-middle latitudinal zone. In general, the absolute Dst index is lower than 20 during the quiet magnetic activity. If it exceeds 50 nT, it means the moderate magnetic storm may occur. Kp is one 3-hour index of worldwide geomagnetic activity level, whose range is from 0 (lower activity) to 9 (high activity). The value is usually lower than 3 if the geomagnetic activity is quiet[18].

### 2.2 Detection method of abnormal information

In the past, the monthly mean or median of TECs is usually selected as the background value to detect ionospheric anomalies. In the paper, we will detect ionospheric anomalies by the sliding inter quartile range. The solar activity has one 27-day cycle because of its rotation. The ultraviolet ray, x-ray, solar wind and other radiations affect the earth magnetosphere to make the ionosphere also contain the 27-day variation[19]. Thus, 27-day cycle will be adopted as the background value to eliminate the influence of ionosphere variation.

According to the theory of sliding inter quartile range[20], the TECs at the same time every day are extracted to compose a time series, and sorted in the ascending order, that is $x_1$, $x_2$, $x_3 \cdots x_{27}$, $x_{28}$. Then the time series is divided into four equal parts, which are lower quartile $Q_1$, mid-quartile $Q_2$, and upper quartile $Q_3$, respectively.

$$Q_1 = \frac{(x_7 + x_8)}{2} \tag{1}$$

$$Q_2 = \frac{(x_{14} + x_{15})}{2} \tag{2}$$

$$Q_3 = \frac{(x_{21} + x_{22})}{2} \tag{3}$$

The interquartile range can be computed as

$$IOR = Q_3 - Q_1 \tag{4}$$

The IOR is approximately equal to 1.34 times the standard deviation. Considering the long background days, the ionosphere is easily influenced by the gradually increasing solar activity. So we take 2 times IOR (about 2.5 times the standard deviation) as the tolerance. The upper and lower bounds are respectively.

$$l_1 = Q_2 + 2IOR \tag{5}$$

$$l_2 = Q_2 - 2IOR \tag{6}$$