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Large-scale traveling ionospheric disturbances using ionospheric imaging at storm time: A case study on 17 march 2013

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ABSTRACT

A moderate geomagnetic storm occurred on March 17, 2013, during which large-scale traveling ionospheric disturbances (LSTIDs) are observed over China by ionosondes and GPS from Crustal Movement Observation Network of China (CMONOC) and the International GNSS Service (IGS). Ionosonde data and computerized ionospheric tomography (CIT) technique are employed to analyze the disturbances in our study. The maximum entropy cross spectral analysis (MECSA) method is used to obtain the propagation parameters of the LSTIDs. Spatio-temporal variations of ionospheric electron density (IED) and total electron content (TEC) during this geomagnetic storm over China are investigated. Disturbance images of IED and TEC are also presented in the paper. The results show two LSTID events at about 12:00 UT and 15:00 UT during the main phase of the storm. Besides, the LSTIDs with a duration of 40 min are detected over China. It is confirmed that the LSTIDs travel from north to south with a horizontal velocity of 400–500 m/s, and moved southwestwards with a horizontal velocity of 250–300 m/s, respectively.

1. Introduction

Geomagnetic storm, as one of the most important phenomena related with solar wind and energetic particle, is a complex process originated from solar wind and magnetosphere. Intensively ionospheric disturbances are often globally excited with the happening of geomagnetic storms. Ionospheric disturbance has received tremendous attention in the field of ionospheric research, and has become an important topic in the investigation of space weather. Study on large-scale traveling ionospheric disturbances (LSTIDs) triggered by solar activity in polar regions can improve the understanding of energy transmission and coupling from polar regions to mid- and low- latitude areas (Tsugawa et al., 2003). Previous statistic studies on ionospheric storms obtained general characters of the disturbances, and further summarized distribution rules of ionospheric storms related with longitude, latitude and season. With the development of GPS technology, new avenues are created for better cognizance of ionospheric space environment.

Owing to the continuous observations and widely distributed stations, GPS has become one of the most important tools to study ionospheric disturbances nowadays (Afraimovich et al., 1998, 2000; Borries et al., 2009; Calais and Haase, 2003; Cander and Mihajlovic, 2005; Ding et al., 2007, 2012; Habarulema et al., 2013; Hernández-Pajares et al., 2006; Ho et al., 1996; Jin et al., 2008; Kotake et al., 2006; Nicolls et al., 2004; Pi et al., 1997; Song et al., 2011, 2012, 2013; Tsugawa et al., 2007a, 2007b; Wang et al., 2007). Ho et al. (1996) observed the LSTIDs during geomagnetic storms with GPS observations from 60 stations all over the world early in 1996, and they detected that increase of total electron content (TEC) was conjugate between north and south hemisphere. Tsugawa et al. (2003) studied ionospheric disturbance during geomagnetic storm in September 22, 1999 with GPS data from GNSS Earth Observation Network System (GEONET), and showed the TEC disturbance images. Wang et al. (2007) conducted a statistic study on propagation parameters of globally traveling ionospheric disturbances during geomagnetic storms occurred during October 29–31, 2013, using GPS observations from over 900 stations, and the southward traveling disturbance with a westward shift was monitored. Geomagnetic storm events were analyzed with respect to the influence on ionosphere in Europe during 2001–2007 were studied by Borries et al. (2009) with GPS observations, compared with TIDs in Japan, Europe has a faster horizontal phase velocity. A study in China was also conducted by Ding et al. (2012), who

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detected two disturbances traveling with the horizontal phase velocity of 540 m/s and 362 m/s respectively during the storm on May 28, 2011. Habarulema et al. (2013) studied the TIDs in South Africa during geomagnetic storms of May 14–16, 2005 and September 25–27, 2011, wavelet analysis was employed to get their propagation parameters. Idrus et al. (2013) investigated the LSTIDs in the regions of high-latitude and equator. Besides, ionospheric disturbances were studied with computerized ionospheric tomography (CIT) technique. Pryse et al. (1995) and Cook and Close (1995) monitored ionospheric disturbances using CIT method. Pryse (2003) further systematically analyzed ionospheric disturbances with CIT. Combining multi-type observations and CIT, Yizengaw et al. (2005) studied ionospheric disturbances during magnetic storms. Wen et al., (2007) studied spatio-temporal evolution of ionospheric electron density (IED) during geomagnetic storms in China. CIT was also applied in monitoring disturbance in North American area by Allain and Mitchell (2010). Yizengaw et al., (2012) obtained disturbance at equatorial region and detected ionospheric trough with the CIT.

This study analyzes large-scale traveling ionospheric disturbance over China during magnetic storm on March 17, 2013, using GPS data from 266 Crustal Movement Observation Network of China (CMONOC) and International GNSS Service (IGS) stations. The inversion result from CIT which is described in detail in the references (Yao et al., 2014) and ionosonde data are used to study ionospheric variation, and TEC disturbance images are presented. The propagation parameters are obtained through the maximum entropy cross spectral analysis (MECSA) method. This paper reports the first results of the horizontal and vertical imaging of LSTIDs using GPS data with MECSA method and CIT technique in China, combined with the observation of TIDs using ionosonde data.

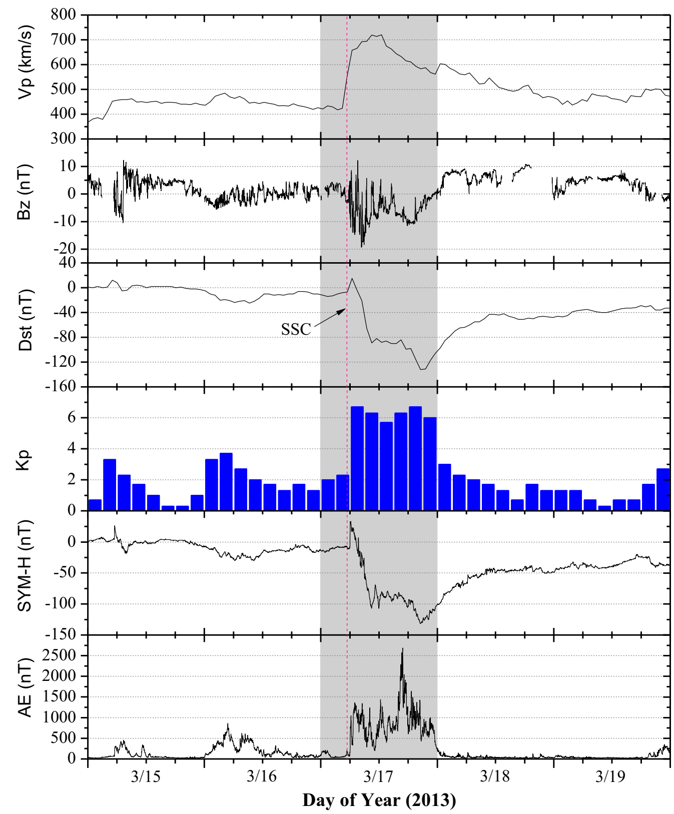

Fig. 2. The magnetic indices solar wind speed (Vp), IMF Bz component, Dst, Kp, SYM-H, and auroral electrojet (AE) during 15–19 March 2013. The gray column denotes the day of 17 March 2013 and the main phase is in 06:00–20:00 UT.

2. Observation processing method

GPS observations from 209 stations of CMONOC and 57 stations of IGS are used to detect ionospheric disturbance over China. Fig. 1 shows the geographic locations of GPS receiver stations (blue dots) and locations of ionosonde stations (red stars) in China and surrounding area. In order to detect the disturbance, the background TEC should be eliminated by filtering. Some scholars used the running average with a time window to estimate the unperturbed TEC level (Kotake et al., 2006; Nicolls et al., 2004; Perevalova et al., 2008; Tsugawa et al., 2003). The high-pass filtering was used by Lee et al. (2008) to detect TEC disturbance. Ding et al. (2007) and Song et al. (2013) expressed the TEC background trend as a function of local time and latitude, they both chose the linear function

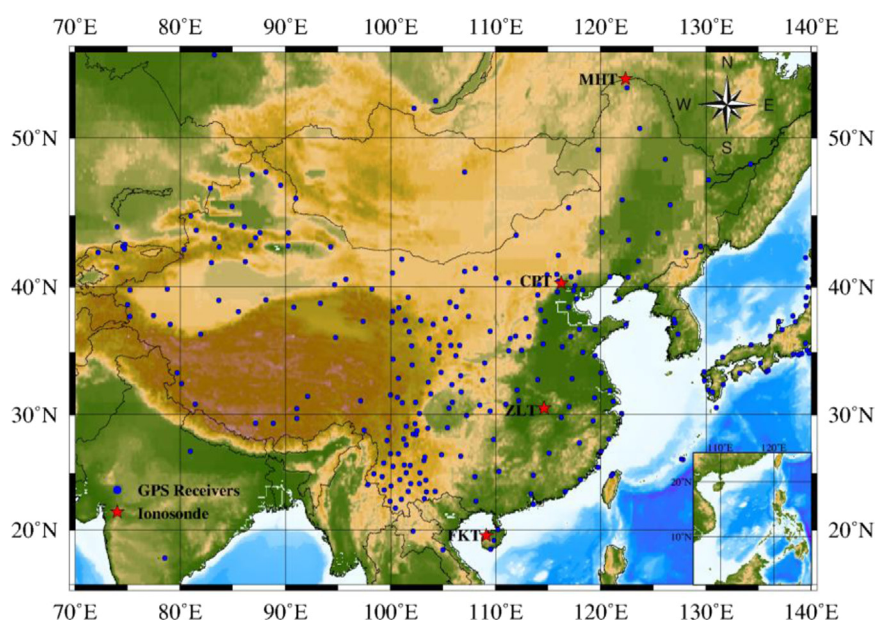

Fig. 1. Locations of GPS receiver stations (blue dots) and locations of ionosonde stations (red stars) in China and surrounding area. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)