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The 2D features of tropical cyclone Usagi's effects on the ionospheric total electron content

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Abstract

The effects of the tropical cyclone Usagi on ionospheric total electron content (TEC) during September 16–24, 2013 are investigated based on the high spatial and temporal resolution TEC data. The Spectral Whitening Method (SWM), a new method to identify aperiodic disturbances, is applied to process the TEC map to ionospheric disturbances map. It is found that the ionosphere is most disturbed along the track of tropical cyclones (TC), and could change its behavior while the typhoon approaching the continent (as well as big island). It is the first result about the 2D features of the ionospheric responses to a tropical cyclone using SWM derived index Js.

Keywords: Tropical cyclone (TC); Ionosphere; Total Electron Content (TEC); Spectral Whitening Method

1. Introduction

Researches showed that severe activities in the lower atmosphere, such as the tropical cyclone (TC), the thunderstorm, the heavy rain and the cold-air outbreak, may impose impacts on the ionosphere (Bauer et al., 1958; Kelley et al., 1985; Kazimirovsky et al., 2003; Liu, 2006). As one of the most severe weather systems in the troposphere, the TC can disturb the ionosphere with its energy and momentum penetrating the middle atmosphere and then reaching the ionosphere (Huang et al., 1985; Isaev et al., 2002; Sorokin et al., 2005; Rishbeth,2006; Xiao et al., 2006, Xiao, 2007; Lin, 2012a,b). Bauer (1958) reported that the critical frequency of F2 layer (foF2) would rise as a response to an approaching hurricane and reach a maximum value after the hurricane center entered the observatory. Shen (1982), however, found foF2 decreases around the landing of TC. The study result of Liu (2006) agreed with Shen (1982) and they proposed this phenomenon could be attributed to the movement of the turbopause's altitude due to the mixing effects of TC. Liu (2006) also argued that the magnitude of ionospheric disturbance is generally proportional to the intensity of related TC and inversely proportional to the distance between TC and observatory. Yu et al. (2010) suggested apparent conflicts among these different results are due to the low temporal resolution of processed foF2 data (24 h moving average of foF2). Benefited from the new observations of higher resolution (15 min) near the Taiwan Strait with high incidence of TC, Yu et al. (2010) reached a conclusion that the foF2 increase before the landing of TCs and decrease after the landing.

But the foF2 data has its limitations: first, the foF2 observations are scattered in land; second, it's of relatively low spatial resolution. So it is difficult (if not impossible) to

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conduct research either at higher temporal-spatial resolutions or above the sea where TCs mainly exist and evolve. Therefore, researchers switch their attentions to the ionospheric total electron content (TEC) data, for the reasons that it has higher temporal-spatial resolutions and is able to cover a part of the ocean area. Polyakova et al. (2011, 2013) showed that the TEC variation amplitudes are highest when the wind speed is the maximum in cyclone and TC area are maximum. Chou et al. (2017) reported the evidence of typhoon induced dispersive concentric traveling ionospheric disturbances using TEC data. Kong et al. (2017) found clear TEC disturbances on the typhoon landing day. Moreover, the great coverage of TEC observations makes it possible to explore the 2D responses of the ionosphere to TCs. Mao et al. (2010) found the TC effects on the ionosphere from a 2D TEC map and TEC variation above the landing site of TC Matsa increased before the landing and decreased after. It is the first try to show a 2D picture about the TC's effects on the ionosphere.

However, the revealing of the relationship between the TEC and TC is restricted by the fact that the TEC variation caused by TC seems to be less than 2TECu which is only 2% or less of the background (Mao et al., 2010; Polyakova and Perevalova, 2011, 2013) and hard to be identified from the noises.

In order to tackle this problem, Wang et al. (2014) and Chen et al. (2014) proposed a new method, the Spectral Whitening Method (SWM), which proves more effective to identify aperiodic disturbances than the methods used in previous studies. In this paper, the SWM is adopted to identify the tiny variations in the ionospheric TEC along the tracks of the TC Usagi.

2. Data and methodology

The TC Usagi occurred on 6:00 UT on September 16, 2013, reached the typhoon phase (with wind speed over 32.7 m/s) at 12:00 UT on September 18, landed in Shanwei City (115.4°E, 22.7°N) at 11:40 UT on September 22, and ended at 0:00 UT on September 24 in Guangxi. The TEC data, obtained from the China Meteorological Administration (CMA) GPS observations, is of 1-h temporal resolution and 0.5° × 0.5° spatial resolution. The foF2 data is of 15-min temporal resolution at Xiamen station (118° 04′E, 24°29′N), which is near the landing site of Usagi. The CMA TC Best Track Data of 1-h temporal resolution and 0.1° × 0.1° spatial resolution provided by the Shanghai Typhoon Institute (http://tcdata.TC.gov.cn) is used (Ying et al., 2014). The Dst data obtained from World Data Center (WDC) (http://wdc.kugi.kyoto-u.ac.jp) of 1-h temporal resolution and F10.7 data obtained from Space Physics Interactive Data Resource (SPIDR) of NOAA (http://spidr.ngdc.noaa.gov/spidr/time.do) of 1-day temporal

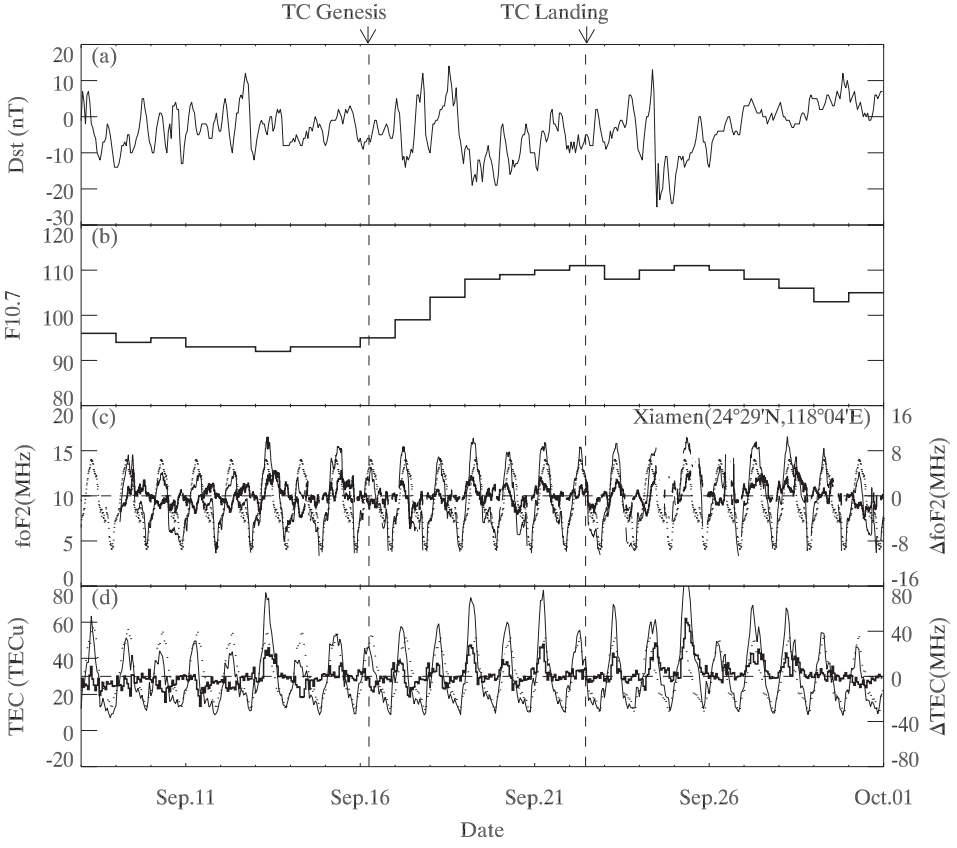

Fig. 1. The Dst index (**a**), F107 index (**b**), observations (thin grey curves), backgrounds (dash-dotted curves) and disturbances derived by MMM (thick black curves) of foF2 (**c**) and TEC (**d**).