GPS TEC OBSERVATIONS OF SUDDEN IONOSPHERIC DISTURBANCES ON THE BASTILLE DAY 2000

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ABSTRACT

Fifty-nine worldwide ground-based global positioning system (GPS) receivers are used to derive the total electron content (TEC) and the time rate of TEC change (rTEC) to monitor the ionospheric solar flare effects on July 14, 2000 (Bastille Day). It is found that sudden ionospheric disturbances occur from dawn to dusk regions, and the most pronounced signatures appear in the dayside region. Results show that TEC is suitable to monitor the overall variations of flare X-ray radiations while rTEC is capable to detect sudden changes in flare X-ray radiations.

INTRODUCTION

A solar flare is a sudden brightening in an active region usually near a complex group of sunspots of the photosphere, which produces immediate increases in the ionospheric ionization of various degrees at different heights, together called sudden ionospheric disturbances (SIDs) or ionospheric solar flare effects [1]. The disturbances have important effects on radio communications and navigations over the entire radio spectrum [2].

To simultaneously observe a large area of ionospheric construction, the global positioning system (GPS) is ideal to be employed. Recently TEC observations by a GPS tracking network became a very common component of scientific studies [3-6]. Since GPS transmitting frequencies are much higher than the ionospheric collision frequencies, the ionospheric absorption (signal fadeout) effects on GPS signals are minor. This allows scientists to detect ionospheric response to solar flares [7].

In this paper, fifty-nine worldwide GPS receivers are employed and grouped into four tracking networks. We derive not only TEC by the GPS-TEC computation method in [5], but also its temporal changing rate (rTEC) to study the ionospheric solar flare effects in the dawn, daytime, dusk, and nighttime regions on July 14, 2000 (Bastille Day) globally and continuously.

OBSERVATION

On the Bastille Day, a solar flare originates near the center of the solar disk. Its brightness has been categorized as the most powerful flare as an X-class flare. The subsolar point of the Earth's ionosphere is located at (23.5°N, 22.5°E geographic). Fifty-nine ground-based receivers are subdivided into four tracking networks to globally observe the ionospheric TEC variations in the dawn (-4°-42°N, 269°-324°E), daytime (17°-62°N, 324°-97°E), dusk (14°-36°N, 97°-144°E), and nighttime (-36°-40°N, 144°-269°E) regions.

Fig. 1 shows the flux intensity of solar X-radiation, the sum of TEC, and rTEC on the Bastille Day. The flux data recorded by the geosynchronous operational environmental satellite (GOES 10) show that flux intensities in 0.5-4 Å and 1-8 Å wavelength reach their maxima at 1023 UT and 1024 UT, respectively. Note that the data are released in 1-min time resolution after smoothing by 5-min running mean. It is found that the ionospheric solar flare effect in TEC is not obvious (marked by a circle), but rTEC reveals a clear signature of the solar flare.

Fig. 2 presents the running mean of solar X-ray flux intensities, the average of TEC and rTEC per satellite and receiver of the four regions during 1000-1045 UT. The most pronounced solar flare effects in TEC and rTEC appear in the daytime region but no clear signature in the nighttime region. TEC yield only one peak at 1029 UT, while rTEC reveals three clear spikes at 1019, 1024, and 1027 UT, respectively throughout dawn, daytime, and dusk regions, especially in daytime region.

To understand the flare effect in detail, daytime TEC and rTEC per receiver from five satellites are investigated. Result shows that TEC from 3 satellites reach their maximum (saturated) values at about 1029 UT, while three clear spikes appear in rTEC from these five satellites at 1019, 1024, and 1027 UT. Moreover, according to the satellite traces, we found that when the number of the satellite traces in the post-noon region is greater than that in the pre-noon region and/or satellites tend to move meridional, TEC variations yield the maximum features.

DISCUSSION AND CONCLUSION

[7] studied the ionospheric disturbances in both TEC and rTEC caused by two powerful impulsive solar flares in 1999 and suggested the GPS rTEC to be a more suitable quantity to identify the disturbances of small solar flares. According to Fig. 2 and 3,TEC and rTEC show two different quantities, which trace the overall and sudden change in the solar X-ray radiations, respectively. There are two types of the X-ray flare radiations, which are the sudden and gradual. The TEC or rTEC can easily detect a great/sudden flare. On the other hand, while the TEC clearly monitors the overall variation of a great/gradual flare, the rTEC might fail to detect anything. Therefore, the suitability and detectability of the two quantities are certainly different.

In summary, the results show that TEC and rTEC are two different quantities, which trace the overall and sudden change in the solar X-ray radiations, respectively. It demonstrates that TEC is suitable to monitor evolutions of the solar flare X-ray radiations, while rTEC can be employed to detect their sudden changes.

ACKNOWLEDGEMENTS

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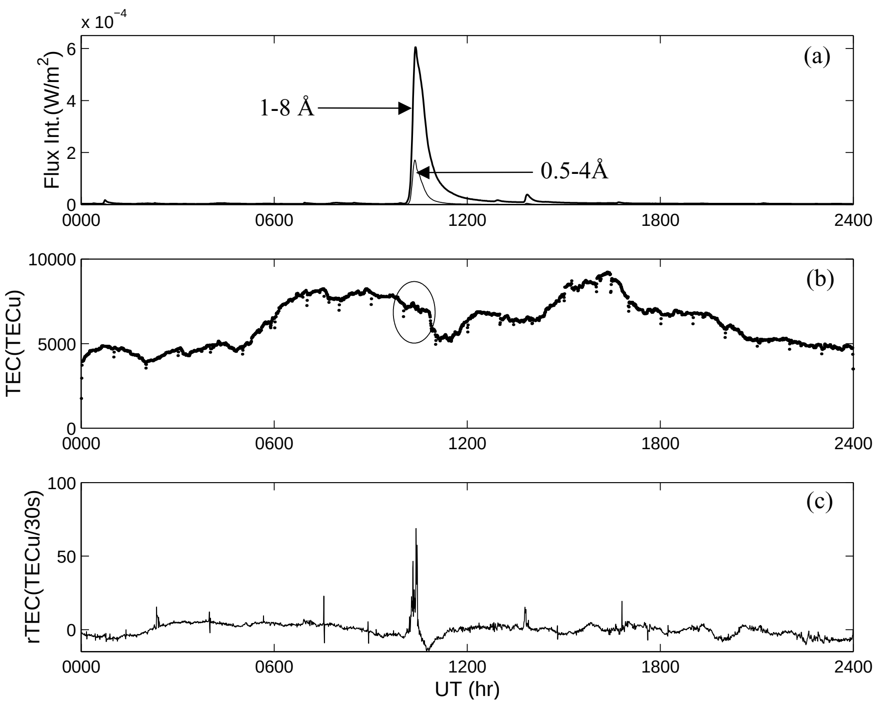

Fig. 1. The solar X-ray flux intensity, the sum of TEC of 59 GPS receivers, and associated rTEC on the Bastille Day.

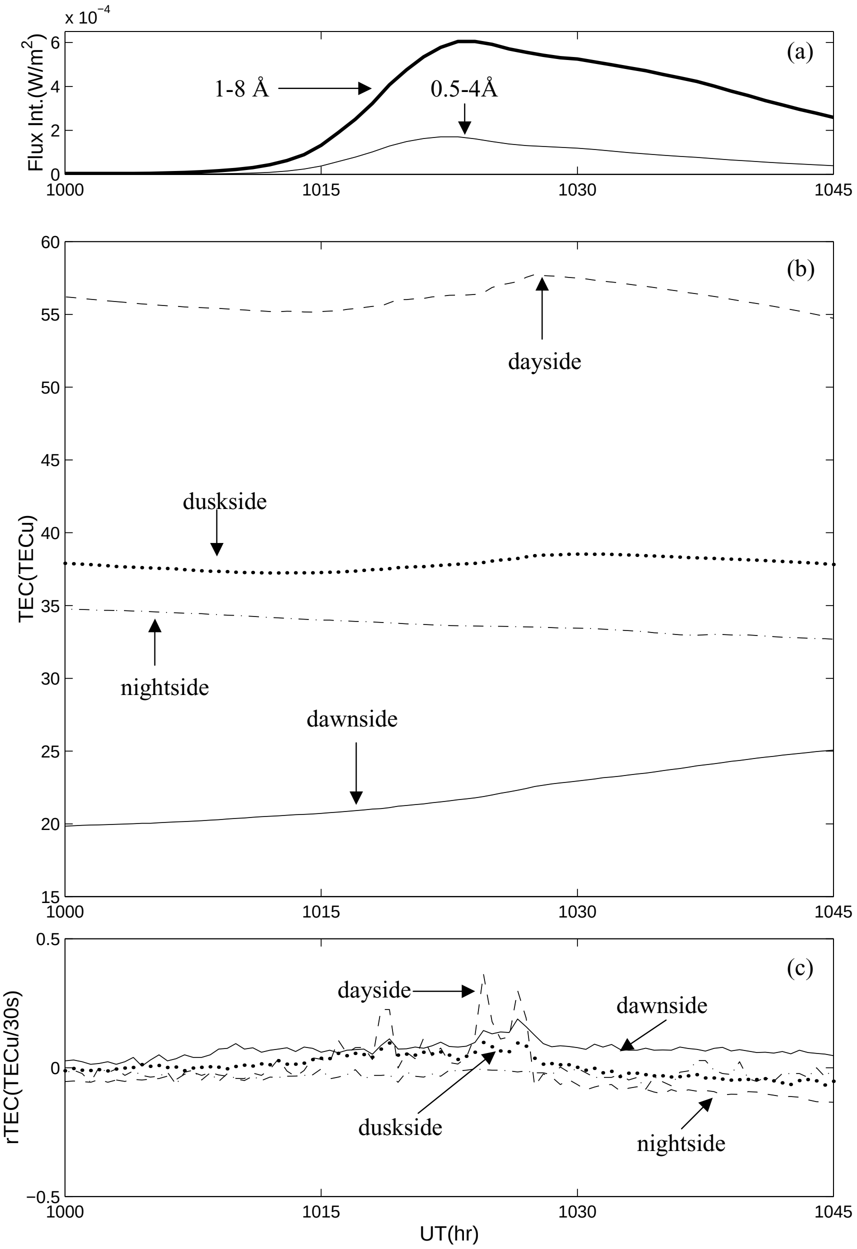

Fig. 2. The solar X-ray radiations, the average of TEC, and its associated rTEC on the Bastille Day, 1000-1045 UT.

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