Responses of equatorial plasma bubbles during geomagnetic storm of October 2016 observed by Beidou GEO TEC observations

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Abstract

The development and evolution of equatorial plasma bubbles (EPBs) have complex behavior during geomagnetic storms. In this study, the Beidou GEO TEC observations from the both low-and-middle latitudinal and equatorial longitudinal GNSS chains were utilized to reveal the responses of EPB in East Hemisphere during the geomagnetic storm of October 2016. The EPBs underwent different variations between the period of quiet and disturbed geomagnetic activity. The generation of EPBs had been enhanced at the main phase of geomagnetic storm when EPBs were induced around sunrise. However, during the geomagnetic recovery phase, the EPBs were totally suppressed, no EPBs were found during those period. Furthermore, the observations from SWARM and ionosnode were used to examine the development and evolution EPBs during the major geomagnetic storm of October 2016. The similar and differences between those observations were analyzed, and the responses of EPBs for geomagnetic storm were discussed.

1 Introduction

Equatorial plasma bubbles (EPBs) are generally irregularity structures with spatial scales ranging from centimeters to hundreds of kilometers in the equatorial ionosphere, which are also known as the equatorial spread F (ESF). They have a plasma depletion and contain irregularity structures that often induce severe ionospheric scintillations. During geomagnetic storm, the energy injection from the solar wind and magnetosphere induces great disturbances in chemical, dynamical and electro-dynamical processes of the ionosphere [e.g., 1-4]. The EPBs will also be affected by the geomagnetic storm due to the ionospheric conditions change. The prompt penetration electric field (PPEF) at the development phase of storm and disturbance dynamo electric field (DDEF) during the recovery phase of storm would alter the ionospheric electrodynamic processes, which play important role in generating of EPBs.

In this study, we have utilized the Beidou GEO TEC observations to reveal the responses of EPB in East Hemisphere during the geomagnetic storm of October 2016. The observations from SWARM and ionosnode were used to further compare that from Beidou GEO TEC. The underlying mechanisms and processes EPBs during the geomagnetic storm were discussed.

2 Dataset

This study focuses on ionospheric total electron content (TEC) observations from Beidou geostationary (GEO) satellites. The advantage of the GEO data is that the ionospheric piece points (IPPs) almost do not change, given that the Beidou GEO TEC observations are not contaminated by the spatial variations due to satellite motion. Previous studies demonstrated that the Beidou GEO TEC gives a fidelity observation to detect the ionospheric variations, compared with the traditional global positioning system (GPS) TEC affected by movement of satellite [e.g., 5-8].

The more GEO TEC observations and the data from SWARM and ionosnode are processing. Their detailed information and results are not introduced here.

3 Results

The geomagnetic storm during October 2016 was one of the major geomagnetic storm events in solar cycle 24. The meridional component of the interplanetary magnetic field (IMF) Bz was suddenly enhanced northward at about 23 UT on 12 October, and this enhancement lasted for about 3 hr. Then, Bz had one major southward reached to about -20 nT lasted one day. Finally, the Bz recovered to 0 nT with small fluctuations about 5 nT. The geomagnetic index Dst dropped to a minimum value of about -115 nT at 0 UT on 14 October 2016, and then recovered gradually.

Figure 1 shows the rate of TEC change index (ROTI) observed by the Beidou GEO TEC at the Asian-Australian sector from 8 to 21 October 2016. The ROTI was first proposed by Pi et al. (1997), which usually has been employed to detect the occurrence of EPB irregularities, with a threshold value of 0.075 TECu/min (Nishioka et al., 2008). From the Figure 1, the EPBs always presented at the post-sunset in the geomagnetic equator before the geomagnetic storm during 8-12 October 2016. During the initial and main phase of geomagnetic storm, the post-sunset EPBs still presented on 13 October, which underwent unobvious change compared with that before geomagnetic storm. However, sudden EPBs were induced around sunrise when the EPBs were absent before geomagnetic storm. During the geomagnetic recovery phase, the EPBs were totally suppressed, no EPBs were found from 14 to19 October 2016. Then, the EPBs still reappeared at post-sunset in the geomagnetic equator after the geomagnetic storm from 20 October 2016. The geomagnetic storm had enhanced the generation of EPBs at the development phase of storm and suppressed the generation of EPBs during the recovery phase of storm.

The other results are analyzing. More detailed results will present in the conference of URSI GASS 2020 in Rome.

4 Summary

In this study, development and evolution of EPBs in East Hemisphere during the geomagnetic storm of October 2016 were investigated using the Beidou GEO TEC observations combined with the observations from SWARM and ionosnode. The geomagnetic storm during the development phase and recovery phase of storm had different role in generating the EPBs. The detailed results and analyses are processing, which are desire to present in the conference of URSI GASS 2020 in Rome

5 Figures

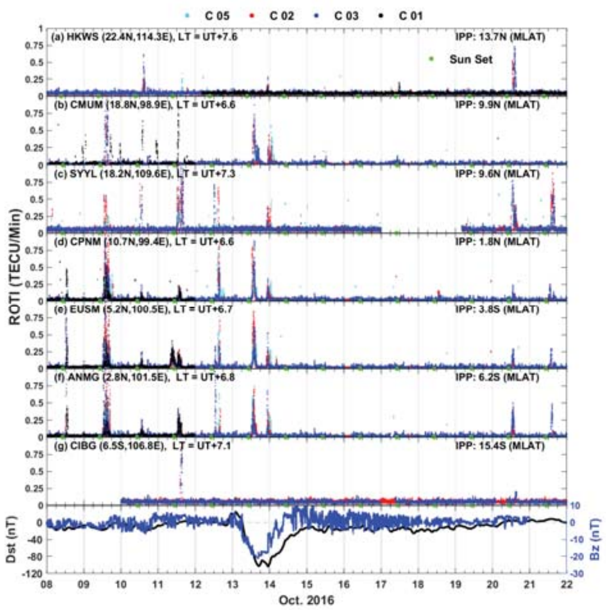

Figure 1. The rate of TEC change index (ROTI) observed by the Beidou GEO TEC at the Asian-Australian sector from 8 to 21 October 2016. The different color lines represented the ROTI from different GEO satellites. The geomagetic index Dst and the meridional component of the interplanetary magnetic field (IMF) Bz were also ploted for reference.

6 Acknowledgements

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7 References

1. A. J. Mannucci, et al., "Hemispheric daytime ionospheric response to intense solar wind forcing, in Inner Magnetosphere Interactions: New Perspectives From Imaging," Geophys. Monogr. Ser., vol. 159, edited by J. L. Burch, M. Schulz, and H. Spence, 2005, pp. 261–275, AGU, Washington, D. C.

2. J. Lei, W. Wang, A. G. Burns, S. C. Solomon, A. D. Richmond, M. Wiltberger, L. P. Goncharenko, A. Coster, and B. W. Reinisch, "Observations and simulations of the ionospheric and thermospheric response to the December 2006 geomagnetic storm: Initial phase," J. Geophys. Res., 113, 2008, A01314, doi:10.1029/2007JA012807.

3. J. Lei, W. Wang, A. G. Burns, X. Yue, X. Dou, X. Luan, S. C. Solomon, and Y. C.-M. Liu, "New aspects of the ionospheric response to the October 2003 superstorms from multiple-satellite observations," Journal of Geophysical Research (Space Physics), 119, 2014, 2298–2317, doi:10.1002/2013JA019575.

4. N. Balan, K. Shiokawa, Y. Otsuka, T. Kikuchi, D. V. Lekshmi, S. Kawamura, et al, "A physical mechanism of positive ionospheric storms at low latitudes and midlatitudes," Journal of Geophysical Research, 115, 2010, A02304, doi:10.1029/2009JA014515.

5. F. Huang, Y. Otsuka, J. Lei, X. Luan, X. Dou, & G. Li, "Daytime periodic wave‐like structures in the ionosphere observed at low latitudes over the Asian‐Australian sector using total electron content from Beidou geostationary satellites," Journal of Geophysical Research: Space Physics, 124, 2019, doi:10.1029/2018JA026443.

6. F. Huang, J. Lei, X. Dou, X. Luan, & J. Zhong, "Nighttime medium‐scale traveling ionospheric disturbances from airglow imager and Global Navigation Satellite Systems observations," Geophysical Research Letters, 45, 2018, 31–38, doi:10.1002/2017GL076408.

7. F. Huang, J. Lei, and X. Dou, "Daytime ionospheric longitudinal gradients seen in the observations from a regional BeiDou GEO receiver network," J. Geophys. Res. Space Physics, 122, 2017, doi:10.1002/2017JA023881.

8. J. Lei, F. Huang, X. Chen, J. Zhong, D. Ren, W. Wang, et al, "Was magnetic storm the only driver of the long-duration enhancements of daytime total electron content in the Asian-Australian sector between 7 and 12 September

2017?," Journal of Geophysical Research: Space Physics, 123, 2018, 3217–3232, doi:10.1029/2017JA025166.

9. X. Pi, A. J. Mannucci, U. J. Lindqwister, & C. M. Ho, "Monitoring of global ionospheric irregularities using the worldwide GPS network," Geophysical Research Letters, 24(18),1997, 2283–2286, doi:10.1029/97GL02273.

10. M. Nishioka, A. Saito, & T. Tsugawa, "Occurrence characteristics of plasma bubble derived from global ground-based GPS receiver networks," Journal of Geophysical Research, 113, 2008, A05301, doi:10.1029/2007JA012605.