URSI GASS 2023, Sapporo, Japan, 19 – 26 August 2023

Temporal and spatial evolution of total electron content enhancements and depletions during substoms

A. Shinbori* (1), Y. Otsuka(1), T. Sori(1), M. Nishioka(2), and S. Perwitasari(2)
(1) Nagoya University, Nagoya, Japan; e-mail: shinbori@isee.nagoya-u.ac.jp; otsuka@isee.nagoya-u.ac.jp; sori.takuya@isee.nagoya-u.ac.jp
(2) National Institute of Information and Communications Technology, Koganei, Japan; e-mail: nishioka@nict.go.jp; septi.perwitasari@nict.go.jp

The signatures of substorm onset show sudden auroral brightening, mid-latitude positive bay, enhancement of total electron content (TEC), and a sharp increase in particle precipitation at high latitudes. Weygand and Wing [2020] found a significant enhancement of TEC occurred within the nightside region 1 field-aligned currents (FACs) system during the substorm expansion phase from a superposed epoch analysis of 239 substorm events. However, they could not clarify the dependence of TEC variations on season and substorm intensity due to the shortage of analyzed substorm events. In this study, we investigate the characteristics of temporal and spatial development of TEC enhancements and depletions from high to low latitudes as a function of season and substorm intensity using long-term Global Navigation Satellite System (GNSS)-TEC data with high time and spatial resolution. Further, we discuss a main cause of the TEC variations during substorms. To monitor the magnetosphere and ionosphere conditions, we also used solar wind, interplanetary magnetic field (IMF), and geomagnetic indices (AE and SYM) data. Here, we analyzed the ratio of the TEC difference defined by Shinbori et al. [2020] to investigate the TEC enhancements and depletions. For identification of substorm events for a period of 2000-2019, we used a list of substorm events derived from the SML index [Ohtani and Gjerloev, 2020]. The statistical analysis shows an increase and decrease of the rTEC value in the pre-midnight (21–0 h magnetic local time (MLT)) and post-midnight (0–3 h MLT) sectors at auroral latitudes (67º–74º geomagnetic latitude (MLAT)) approximately 1 hour before the substorm expansions for the weak substorm events (maximum AE < 500 nT) in equinoxes. The post-midnight rTEC depletion corresponds to the high-latitude trough [Rodger et al., 1992] and is generated by the evacuation of upward FACs due to the enhancement of the nightside substorm current wedge [Zou et al., 2013]. Further, another rTEC enhancement occurs in the polar cap (more than 80º MLAT). This enhancement corresponds to a tongue of ionization (TOI) phenomenon caused by a significant increase of two-cell convection at high latitudes. After the substorm expansion, the enhanced rTEC region in the post-midnight sector shows a rapid extension to the post-midnight sector (~6 h MLT) within 1 hour. At this time, the depth of mid-latitude trough below the enhanced rTEC region tends to increase significantly in the dusk sector (17–22 h MLT). For the medium substorm events (500 <= maximum AE < 1000 nT) in equinoxes, the similar features of the rTEC variations can be seen at high latitudes but the rTEC enhancement appears in the afternoon sector (12–18 h MLT) from high to mid-latitudes (55º–75º MLAT). The enhanced rTEC region extends to the low latitudes and midnight with time. This behavior is almost similar to that of a storm-enhanced density (SED) phenomenon.

References

[1] J. M. Weygand and S. Wing, Temporal and spatial development of TEC enhancements during substorms, *J. Geophys. Res.*, **125**, e2019JA026985, doi:10.1029/2019JA026985, 2020.

[2] A. Shinbori, Y. Otsuka, T. Sori, T. Tsugawa, and M. Nishioka, Temporal and spatial variations of total electron content enhancements during a geomagnetic storm on 27 and 28 September 2017, *J. Geophys. Res.*, **125**, e2019JA026873, doi:10.1029/2019JA026873, 2020.

[3] A. S. Rodger, R. J. Moffett, and S. Quegan, The role of ion drift in the formation of ionization troughs in the mid- and high-latitude ionosphere–A review, J. Atms. Terr. Phys., 54, 1-30, doi:10.106/0021-9169(92)90082-V, 1992.

[4] S. Zou, M. B. Moldwin, M. J. Nicolls, A. J. Ridley, A. J. Coster, E. Yizengaw, L. R. Lyons, and E. F. Donovan, Electrodynamics of the high-latitude trough: Its relationship with convection flows and field-aligned currents, J. Geophs. Res., 118, 256502572, doi:10.1002/jgra.50120, 2013.