Temporal and spatial variations of the ionosphere and plasmasphere during geomagnetic storms on the basis of global Total Electron Content (TEC) data analysis

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It has been well-known that the global structures of the ionosphere and plasmasphere are drastically changed during the main and recovery phases of geomagnetic storms. These variations represent a complex response of the ionosphere-thermosphere-plasmasphere system to geomagnetic disturbances. Previous studies showed (1) a large enhancement of Total Electron Content (TEC) in the equatorial and middle-latitude regions within a few hours during a severe geomagnetic storm [e.g., Mannucci et al., 2005], (2) formation of storm-enhanced electron density (SED) extending from middle to high latitudes [e.g., Foster, 2013], and (3) physical process of SED formation and variation of the equatorial ionosphere on the basis of global SAMI3-Rice Convection Model (RCM) simulation [Huba and Sazykin, 2014]. However, these studies did not investigate detailed temporal and spatial variations of the ionosphere and plasmasphere with high time resolution during the main and recovery phases of geomagnetic storms using global TEC data. In this study, we clarify the temporal and spatial variations of the ionosphere and plasmasphere associated with development and decay of the geomagnetic storm occurred on October 11-12, 2010, on the basis of global TEC data obtained from Global Navigation Satellite System (GNSS) data. Moreover, we investigate the temporal and spatial variations of the plasmapause location from identification of ionospheric trough region from the latitudinal distribution of TEC. In this analysis, we used the geomagnetic Kp and SYM-H induces and global TEC data, and the Inter-university Upper atmosphere Global Observation NETwork (IUGONET) data analysis tool [Tanaka et al., 2013]. These data are provided by World Data Center for Geomagnetism, Kyoto University, and Dense Regional And Worldwide INternational GNSS-TEC observation (DRAWING-TEC) project, NICT [Tsugawa et al., 2007], respectively. We first produced a global distribution of the 5-day quiet-time average TEC in a month of the investigated storm event. Here, we identified the 5 quiet days as a summation of the Kp index in each month. As a next step, we created a global map of difference of TEC (d-TEC) in between the storm-time and quiet-time periods, and investigated the global variation of the d-TEC during the main and recovery phases of the geomagnetic storm. During the pre-storm and initial phase of the geomagnetic storm, the d-TEC showed a small variation with the amplitude of less than 3 TECU for geographical latitude and longitude except for the equatorial and low-latitude (< 30 degrees, GMLAT: geomagnetic latitude). The spatial distribution of d-TEC did not almost change during this period. After the sudden commencement identified as a step-like increase of the SYM-H index, the d-TEC value began to increase in the middle-low latitudes (30-55 degrees) of the morning sector (9-10 h, LT: local time). As the geomagnetic storm is developed, the enhanced d-TEC region expanded to the afternoon sector (15 h, LT) within 4-5 hours. Moreover, 4 hours after the start of the main phase, the ionospheric trough region where the d-TEC value decreases significantly appeared in the afternoon sector (14 –17 h, LT), and the location moved equatorward (67 to 54 degrees, GMLAT) associated with the development of the geomagnetic storm. This indicates that the plasmapause moves earthward in association with an intensification of convection electric field. On the other hand, in the high-latitude region (> 60 degrees, GMLAT) of the morning sector (10-11 h, LT), a plume-like structure of d-TEC appeared, which corresponds to the SED phenomenon. The ionospheric trough and SED disappeared within 1 hour after the start of the recovery phase of the

geomagnetic storm. The disappearance of these phenomena suggests that the SAPS/SAID activity and convection electric field decrease associated with the recovery phase of the geomagnetic storm.

Keywords: Geomagnetic storm, Total Electron Content (TEC), Ionosphere-Plasmasphere, Ionospheric electric field, Ionospheric trough, Plasmapause

