Temporal and spatial variations of the ionosphere and plasmasphere during geomagnetic storms as seen in global Total Electron Content (TEC) data

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The global structure of the ionosphere and plasmasphere is drastically changed during geomagnetic disturbances such as storms and substorms, and the response of the ionosphere and plasmasphere to geomagnetic disturbances is very complicated.. 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, 1993], 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 on the basis of global TEC data analysis. In this study, we analyzed the temporal and spatial variations of ionospheric trough associated with development and decay of geomagnetic storms with the global TEC data in order to clarify the variation of the plasmapause location. 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 10-day quiet-time average TEC in a month of investigated storm events. 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 geomagnetic storms. During the pre-storm and initial phase of geomagnetic storms, d-TEC showed a small variation with the amplitude of less than 3 TECU except for the equatorial and low-latitude (less than 30 degrees, GMLAT: geomagnetic latitude). After the sudden commencement identified as a step-like increase of the SYM-H index, d-TEC began to increase in the middle-low latitudes (30-55 degrees) of the morning sector (9-10 h, LT: local time). As geomagnetic storms grow, the enhanced d-TEC region expanded to the afternoon sector (15 h, LT) within 4-5 hours. 4 hours after the start of the main phase, the decreased d-TEC region with a line structure in a longitudinal direction, which is identified as an ionospheric trough, appeared in the afternoon sector (14-17 h, LT). The location moved equatorward with a wavy structure with a scale of 500-1000 km in a longitudinal direction associated with the development of geomagnetic storms. This implies that the plasmapause move earthward with a spastically inhomogeneous structure in association with an intensified convection electric field with a small-scale structure. On the other hand, in the high-latitude region (more than 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.

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