A new perspective of the storm-time dynamics of the ionosphere using global GNSS-TEC observation data

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The Earth's atmosphere is divided into four regions: troposphere, stratosphere, mesosphere and thermosphere by the temperature structure. A part of neutral gases in the mesosphere and thermosphere is ionized by solar extreme ultraviolet (EUV) radiation in a wavelength of less than 100 nm. The region having the ionized gasses (plasmas) is called the ionosphere. The height profile of the electron density in the ionosphere becomes maximum at a height of 300 km is determined by the chemical and dynamical processes in addition to the solar EUV ionization. Due to the interaction between the ionospheric electrons and electric fields of electromagnetic waves, the ionosphere gives a significant influence on the ionospheric transmissions with satellites for communications, positioning, and navigation. The ionosphere changes greatly in association with the activities of the sun, magnetosphere, and the lower atmosphere, and their ionospheric variations interfere with satellite communication and enhances satellite positioning errors in the Global Navigation Satellite System (GNSS), including GPS. The most major factor of the positioning errors is the propagation delay of GNSS signals in the ionosphere. Therefore, a global total electron content (TEC) map or ionospheric model is required to investigate global ionospheric variations associated with geomagnetic storms and lower atmospheric activities and to evaluate the ionospheric delay for GNSS positioning. A scale of the ionospheric variations (traveling ionospheric disturbances (TIDs), equatorial plasma bubbles (EPB), auroral ionospheric irregularity) is in a range between several 100 km and 1000 km. A storm enhanced density (SED) phenomena observed in the mid- and low-latitude ionosphere during the main phase of geomagnetic storms appears with a wide longitudinal extent. In order to clarify generation and propagation mechanisms of these ionospheric phenomena and to investigate their effects on the GNSS positioning, dense and wide-coverage ionospheric observations and the corresponding TEC data are needed. Under these backgrounds, we have built a global TEC database (absolute TEC, detrended TEC, and ROTI) with high time and spatial resolutions and developed a TEC data analysis system in a corroboration with NICT and the IUGONET (Inter-university Upper atmosphere Global Observation NETwork) and PWING (Study of dynamical variation of particles and waves in the inner magnetosphere using ground-based network observations) projects. For the development of the TEC database, we have collected all the available GNSS receiver data in the world. The number of the GNSS stations reaches more than 8500 in January 2019. These GNSS data are provided by the International Geoscience Services (IGS), the University NAVSTAR Consortium (UNAVCO), Scripps Orbit and Permanent Array Center (SOPAC), and other global and regional data centers (more than 50 data providers in all). In this talk, we introduce an overview of recent new scientific results of temporal and spatial variations in the ionosphere during the development and decay of geomagnetic storms as seen in the global GNSS-TEC variations.

Keywords: Global Navigation Satellite System (GNSS), Ionosphere, Geomagnetic storm, Positioning error, Total electron content (TEC), Database

