GNSS observation of ionospheric variation due to perturbations near the Earth’s surface

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Both solar activity (e.g. solar flare, coronal mass ejection, and moon shadow) and perturbations from the lower atmosphere (e.g. cyclone, walker circulation, and El Niño - Southern Oscillation) and ground (e.g. earthquake, tsunami, and volcanic eruption) change the ionospheric structure. The ground- and space-based Global Navigation Satellite System (GNSS) is a powerful technique for capturing atmospheric variabilities in both horizontal and vertical directions at various altitudes, that help us to seek a deeper understanding of the solar-terrestrial environment. Other than the impact of solar activities, numerous ionospheric phenomena that result from perturbations from lower atmosphere and ground remain unexplained. This study first shows the effect of longitudinal distribution of convection, such as El Niño - Southern Oscillation (ENSO), on the quasi-biennial oscillation (QBO) from the stratosphere (U30 index) to ionosphere at low latitude. The ENSO signals in the QBOs at various altitudes are observed by the FORMOSAT-3/COSMIC radio occultation (RO) sounding profiles of temperature and electron density. The RO technique records ENSO signals which are pertinent to the ongoing study attempting to establish the long-term change in the troposphere connection to the upper atmosphere. Moreover, surface perturbations due to a large earthquake and tsunami can also significantly perturb the ionosphere. The horizontal movement of seismo-traveling atmospheric disturbance (STAD) in the ionosphere have been comprehensively observed by dense ground-based GNSS networks. However, evidence for the vertical component of STAD is rare. This study shows that the 2010 Mw8.8 Chile, 2011 Mw9.0 Tohoku, and 2015 Mw7.8 Nepal earthquake/tsunami can perturb the vertical structure of not only the ionosphere but also the stratosphere. The detection of STAD in the lower atmosphere and a more comprehensive understanding of STAD propagation in the whole atmosphere benefit to earthquake/tsunami early warning system.

Keywords: GNSS, ionospheric weather, surface perturbation

