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Large changes in electron density (Ne) production and composition occur at different spatial and temporal scales during the period of geomagnetic disturbed conditions. Significant release of plasma along with enhanced X-ray and EUV emissions during Coronal Mass Ejections (CMEs) cause disturbances in the ionosphere and thermosphere (IT) system and manifests ionospheric perturbations in Ne and atomic and molecular excitations. In addition, diurnal variations of Ne production in the ionospheric layers can further complicate the Ne responses. In order to characterize the IT system responses during the storm events, we utilize topside Total Electron Content (TEC) from Precise Orbit Determination (POD) GNSS receivers, as well as Ne retrieval profiles from GNSS-RO receivers, onboard in COSMIC-1, GRACE, and MetOp-A/B missions. Upward looking slant-path TEC observations are obtained at different orbital altitudes: ~450km (GRACE), ~800km (COSMIC-1, MetOp), and converted to vertical TEC at respective altitude levels using mapping function. The time series of TEC or Ne changes are analyzed for different phase periods of the geomagnetic storms. During the initial phase when the CME energy arrives at polar and auroral latitudes, depletions in the GNSS-RO Ne and TEC start to occur at high latitudes. In the meantime, enhancements and depletions in Ne and TEC occur at low and mid-latitudes during the main and recovery phases of the storm. A lagged response is found in perturbations between high- and low-latitude. However, the observed lagged responses in the northern and southern hemispheres are asymmetric with respect to the magnetic equator and they are more evident in the summer hemisphere. In this paper, we will present the detailed extraction method of storm-induced perturbations and the treatments for the sampling effects and diurnal variability. For comparison purposes, we also estimate RO TEC using Ne profiles, for given altitude window. Although the number of RO TEC is much fewer than one from POD TEC due to the limited availability of Ne retrieval profiles, the comparison between RO TEC and POD TEC shows agreement.
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