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Probing geo-storm driven ionospheric irregularities in the upper and lower ionosphere and its effects on satellite aerodynamics in low Earth orbit

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We combined simultaneously observed diagnostics of the lower ionosphere (D-region) with high frequency (HF) radio pulses (ionosonde) in the E and F regions, and GNSS observations to investigate geomagnetic storm-induced ionospheric irregularities propagating from the upper to the lower ionosphere in the magnetosphere-ionosphere (I-T) system. We probed the D region using characterized metrics of very low frequency (VLF) signals (obtained from GQD-A118 and DHO-A118 propagation paths) such as the mean amplitude before sunrise (MBSR), daytime mean amplitude (DTMA) and mean amplitude after sunset (MASS). We analyzed trends in the variation of signal metrics during storms, to attribute the deviations in the signal amplitudes that were attributable to the storms. Relative to pre-storm day levels, the storm-day signal strength showed significant decrease in the DTMA, MBSR and MASS with characteristic strong responses of DTMA especially in DHO-A118 (Germany-France) propagation path. Analysis of the the virtual heights (h'E, h'F1 and h'F2) and critical frequencies (foE, foF1, and foF2) from ionosondes located near the transmitter sites showed significant increases and fluctuations in both the F-region parameters above the transmitters in association with the geomagnetic storms, with the largest increases in the virtual heights observed near the DHO transmitter. The measurements of the total election content (TEC) obtained from multiple stations near the transmitter and receiver sites also showed larger enhancements of electron density near the DHO transmitter. These results are consistent with the findings in previous investigation [1,2], and demonstrates the spaciotemporal variability of the I-T system, which produces local asymmetries in ionospheric regions with DHO-A118 path (in this case) exhibiting stronger responses to the storms. We also modeled and obtained estimate of short-term effect of atmospheric drag on satellites aerodynamics in low Earth orbit (LEO) due to the storm-induced ionospheric perturbations.

1. Nwankwo V.U.J., Raulin J-P., Correia E., Denig W., Folarin O., Ogunmodimu O and De Oliveira R.R., 2021. Investigation of ionosphere response to geomagnetic storms over the propagation paths of very low frequency radio waves. AGU Radio Science, 2020RS007203T, doi.org/10.1002/essoar.10504067.1, in review, 2021.
2. Nwankwo, V.U.J., Chakrabarti, S.K., Denig, W., Ogunmudimu, O., Ajakaiye, M.P., and Anekwe, P.I.: Diagnostic study of geomagnetic storm-induced ionospheric changes over VLF signal propagation paths in mid-latitude D-region, Ann. Geophys. Discuss. [preprint], https://doi.org/10.5194/angeo-2021-42, in review, 2021.