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Storm generated large scale TIDs (LSTIDs): local, regional and global observations during solar cycles 23-24

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Large scale traveling ionospheric disturbances (LSTIDs) are a key dynamic ionospheric process that transports energy and momentum vertically and horizontally during storms. These disturbances are observed as electron density irregularities in total electron content and other ionospheric parameters. This study reports on various explorations of LSTIDs characteristics, in particular horizontal and vertical propagation, during some major/severe storms of solar cycles 23-24. We have employed GNSS TEC to estimate horizontal propagation and radio occultation data from COSMIC/FORMOSAT-3 and SWARM satellites to estimate vertical motion. The work presented here reveals the evolution of the characterisation efficiency from using sparsely populated stations, resulting in limited spatial resolution through rudimentary analysis to more densely populated GNSS network leading to more accurate temporal and spatial determinations. For example, early observations of LSTIDs largely revealed unidirectional propagation whereas later studies have showed that one storm can induce multi-directional propagation, e.g. Halloween 2003 storm induced equatorward LSTIDs on a local scale whereas the 9 March 2012 storm induced simultaneous equatorward and poleward LSTIDs on a global scale. This later study, i.e. 9 March 2012 storm, revealed for the first time that ionospheric electrodynamics, specifically variations in ExB drift, is also an efficient generator of LSTIDs. Results from these studies also revealed constructive and destructive interference pattern of storm induced LSTIDs. Constellations of LEO satellites such as COSMIC/FORMOSAT-3 and SWARM have given sufficient spatial and temporal resolution to study vertical propagation of LSTIDs in addition to the meridional propagation given by GNSS TEC; the former (i.e. vertical velocities) were found to fall below 100 m/s.