Monitoring and understanding of plasma irregularities induced by Space Weather

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Gaining new knowledge on morphology and spatio-temporal dynamics of the ionospheric plasma irregularities, their dependences on geophysical factors, is an important and challenging task. Several years ago, the International GNSS Service (IGS) has accepted for official release a new ionospheric product – ROTI maps to monitoring intensity of ionospheric irregularities as derived from multi-site ground-based GPS observations. This product is routinely generated by multi-step processing of carrier phase delays in dual-frequency GPS signals and transferred to the IGS CDDIS database. IGS ROTI maps represents changes of the GPS-based index ROTI (Rate of TEC Index) and has a polar projection within a range of 50°-90°N in geomagnetic latitude and 00-24 magnetic local time. As the highest concentration of the GNSS users is within the American, European, and Asian sectors, initially it focused on the Northern Hemisphere auroral and midlatitude regions. But plasma irregularities that occurred at high, middle, and low latitudes have different physical mechanisms of their origin and development. For investigation of the ionospheric irregularities' climatology, study of the ionospheric responses for Space Weather events, processes derived from below, this actual ROTI Map product is required to be extended to lower latitudes and the Southern hemisphere polar and midlatitudes.

On the case of the strong 22–23 June 2015 geomagnetic storm, we demonstrate importance of this extension. During geomagnetic storms, plasma irregularities occurring at midlatitudes have typically an auroral origin and resulted from energetic particles precipitations in subauroral region. However, an unpredictable extreme event is an occurrence of plasma irregularities of equatorial origin at midlatitudes. The storm-induced prompt penetration electric fields can cause an occurrence of the severe plasma bite-outs in the post-sunset sector over equatorial latitudes and development of large-scale plasma bubbles extended toward midlatitudes. Development of such super plasma bubbles can cause GNSS performance degradation. We examine global features of the large-scale plasma depletion by using a combination of ground-based and space-borne measurements - ground-based GNSS networks, COSMIC GPS RO, Swarm GPS and in-situ observations, and in situ data from onboard the C/NOFS satellite. It was investigated relationships between space weather drivers and processes of plasma irregularities development in order to reveal global drivers that originate these processes. We also demonstrate to which extent an integration of independent but compatible modern ground-based and space-borne observations can support understanding on the origin and dynamics of ionospheric plasma irregularities and to estimate physical drivers leading to these structures' generation.

Keywords: ionosphere, irregularities, ROTI, IGS, plasma bubbles