Visualization and characterization of the regional and continental TEC inhomogeneities based on the dense networks of GNSS receivers

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The total electron content (TEC) is a quantitative parameter which spatial distribution corresponds to the distribution of the ionospheric heterogeneity. In this study we show the method and the results of modeling medium-scale non-stationary ionospheric inhomogeneities. Our analyzes were conducted based on TEC maps created separately for each observation epoch and for each GNSS satellite. Such approach allows eliminating errors during combining data from multiple satellites. Creation of high-resolution maps is possible by using observations from dense networks of GNSS receivers. Utilization of data from the separated satellites has two advantages which avoid misinterpretations of the results. Firstly, there is no overlap of the estimated TEC. Secondly, comparing individual maps for several satellites can be used for estimating an altitude and thickness of the ionospheric inhomogeneities. Therefore, we are able to develop 4D (3D space and time) characterization of the phenomena. On the other hand, the two-dimension model represented by the regional or continental TEC variation maps allows visualization and classification of the spatial structures. Classification is based on visible morphological characteristics, e.g. spatial periodicity, and statistical parameters of spatial distribution.

In this study analyzes and characteristics of the ionospheric inhomogeneities observed over Central Europe and the USA are presented. We focused on two geomagnetic storms occurred in St. Patrick's Day in March 2013 and 2015. We show correlation coefficients estimated in space and time, and we defined characteristics periods occurred during the phenomena. For the analyzed periods, the root mean square (RMS) of TEC variations in diurnal cycles were calculated. We noticed significant increase of RMS during the geomagnetic storms occurred on St. Patrick's Days. It amounts more than 1 TECU in 2015. For comparison, on the days with quiet conditions, the RMS values were below 0.1 TECU. Based on the TEC variations maps estimated every 30-sec the motion parameters were also estimated. We obtained similar results during the quiet days in 2013 and 2015, while during the main phase of the storms increased velocities were observed. Moreover, we found out that several times a day, a quasi-deterministic wave-like variations appear, which have similar speed as thermospheric winds at the height of the maximum of the F2 layer (hmF2) but they characterized by the opposite direction.

Utilization of the TEC variations maps obtained separately for two near-zenith satellite allows us to estimate the height of the ionospheric inhomogeneities (HII). During the quiet days the obtained results are similar to the hmF2 derived from the ionosondes. The HII increased significantly during the active phase of the storm which proved to be convergent with the changes of the slab ionospheric thickness and protons flux at the POES satellites orbit.