Multi–instrumental diagnostics of multi–scale ionospheric irregularities

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Abstract

The scientific goal of this dissertation was to develop a real-time ionospheric product – ROTI (*Rate Of TEC Index*) maps, based on multi-constellation GNSS (*Global Navigation Satellite Systems*). Work on this product was also carried out under the project „ARTEMIS: Advanced methodology development for Real-Time Multi-constellation (BDS, Galileo and GPS) Ionosphere Services" funded by The National Centre for Research and Development (NCBR) and Ministry of Science and Technology (MOST). As part of this project, the author, as one of the main contractors and a member of the IGS Ionospheric Working Group, was responsible for developing European regional ROTI maps based on a multi-constellation approach and available in real time. The goal was to verify the research thesis that: *ROT and ROTI indices obtained from multi-constellation GNSS observations are an efficient and reliable tool for monitoring ionospheric disturbances, complementary to other techniques.*

As part of achieving the goal and verifying the thesis, a number of research tasks were performed: 1) the availability of GNSS data was assessed, taking into account individual constellations and real-time data streams availability; 2) the impact of the number of observations on the quality of ROTI maps was assessed, taking into account various constellation configurations and the internal consistency of elaborations from individual systems; 3) a long-term climatological ROTI analysis was carried out to assess diurnal, seasonal and long-term variability driven by the 11-year cycle of solar activity; 4) an analysis of the behavior of ROTI at medium and high latitudes during periods of increased ionospheric activity associated with the occurrence of magnetic storms was carried out – as part of the assessment, direct plasma density measurements from the Swarm satellite mission were also used for validation purposes; 5) the possibilities of monitoring ionospheric structures using ROTI maps were assessed against other methods: ΔTEC maps, in-situ measurements using Swarm satellites and radio astronomy observations carried out by the LOFAR (*LOw Frequency ARray*) system.

Based on the abovementioned analyzes and completed tasks, it can be concluded that the developed ROTI maps, as a reliable, efficient and complementary tool with

other techniques, can be the core of a multi-instrumental system describing a full range of ionospheric structures. The product developed within the dissertation, after the test period and approval by the IGS board, will be an extension of the currently existing fluctuation product – ROTI maps for the northern hemisphere developed with daily resolution based on GPS observations.

Keywords: ionosphere, multi-GNSS, ROTI, ionospheric irregularities, space weather