MEASUREMENTS OF TIDs PARAMETERS BASED ON DENSE NATIONAL GNSS NETWORKS IN CENTRAL EUROPE

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MEASUREMENTS OF TIDS PARAMETERS BASED ON DENSE NATIONAL GNSS NETWORKS IN CENTRAL EUROPE

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Introduction

Traveling ionospheric disturbances (TIDs) are relatively stable spatial structures characterized by a certain distribution of the electron concentration, which moves as a whole, especially in the horizontal direction. In most cases, TIDs are associated with atmospheric gravity waves and are expected to be a quasi-wave. One of effective and modern method of studying TIDs movements, is sounding of the ionosphere by GNSS signals collected by the dense national networks of permanent stations.

Technique of the orthogonal projection of variations of electronic content of the ionosphere (OPVECI) for the total electron content (TEC) mapping, allows for the ionospheric irregularities visualization. In this study, we used this approach to detect TIDs, model them and measure their parameters, such as direction and speed of movement or spatial period. TIDs were detected regularly, up to several times a day, and were observed within time periods from a few tens of minutes to hours.

In most cases, the directions of movement were opposite to direction of the horizontal wind, calculated by HWM 07 model at the height of maximum of F2 ionospheric layer.

Method

The ionosphere radio sounding algorithm, based on GNSS signals observed from near zenith satellites (elevation cut-off angle > 70°) by dense network of GNSS stations, was used. In such case, the total electron content is measured directly above receivers and therefore spatial resolution is determined by the distance between them. This method of Orthogonal Projection of Variations of Electron Content of Ionosphere (OPVECI) is similar to orthogonal parallel-beam projection used in medicine radiographic.

For each GNSS station used in this study, variations of STEC were calculated for near zenith satellites, which allowed to obtain map of point presented in Figure 3. The next step was to generate regular grid with the 0.2°x0.2° mesh, using bilinear interpolation.

Mapping was conducted without averaging in time, so temporal resolution was determined by sampling rate of receivers - 30 seconds.

In presented solution only GPS phase observations were used.

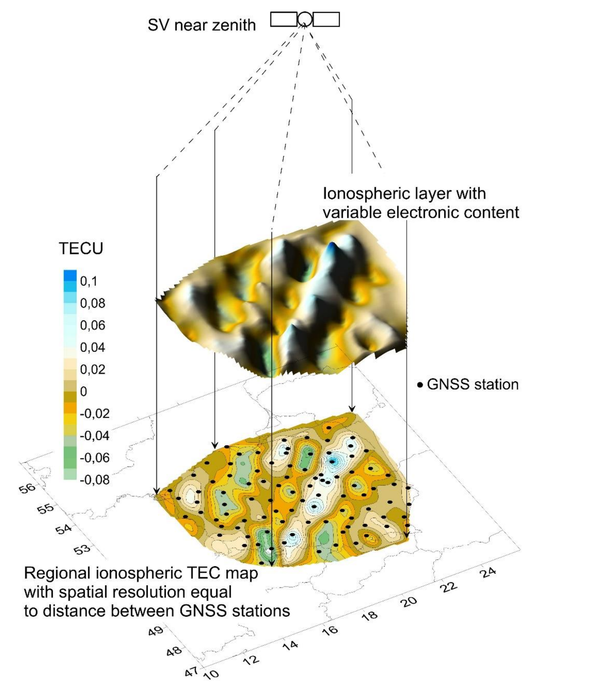


Fig. 1. Scheme of TEC mapping obtained by method of orthogonal parallel-beam projection.

Data

The aim of this study was to use the advanced mapping algorithm for the measurements of the ionospheric irregularities parameters, using data of several dense national-wide networks in Central Europe. We used observation data (30-seconds RINEX files) from 5 countries: Germany (SAPOS network), Czech Republic (CZEPOS), Poland (ASG-EUPOS and Leica SMARTNET), Slovakia (SKPOS) and Hungary (GNSSnet.hu). Additionally EPN stations from Austria were used. The total number of stations amounted to 590 and 696, respectively in 2013 and 2015 (Fig. 3).

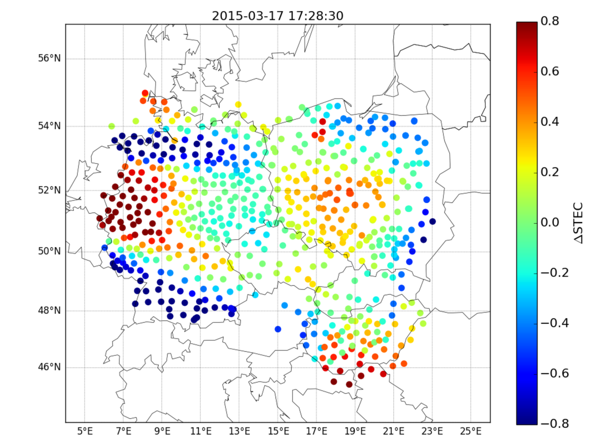


Fig. 2. Example map of STEC variations points.

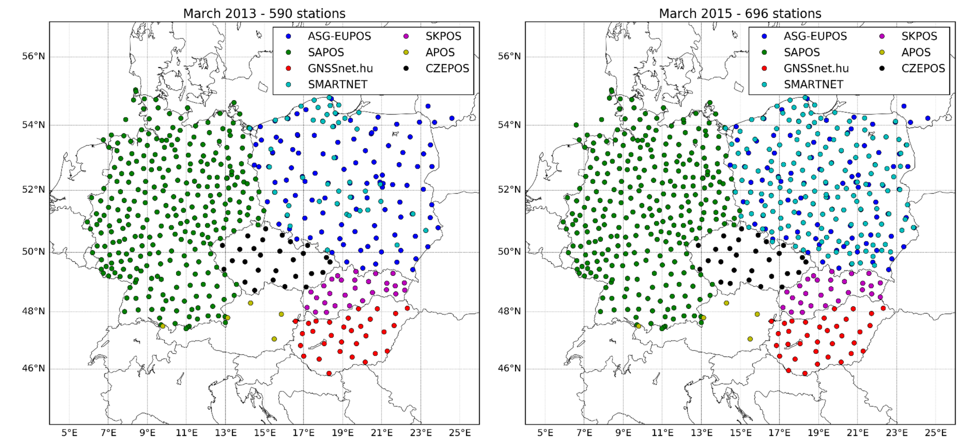


Fig. 3. Stations used in this study in 2013 (left) and 2015 (right).

Results

Figure 4 shows map of the STEC variations on March 13 2013 at 08^h50^m, at the time of day far from terminator event, in quiet geomagnetic activity (Kp=0). Its ACF function is shown in Figure 5 on the left. Cross section (the central profile) of ACF and the corresponding spectrum is presented in Figure 5, right. The modulation period was estimated as 170 kilometers. Profiles of STEC variations along the 52° parallel from 08^h30^m to 09^h00^m on March 13, 2013, as "waterfall" and in the coordinates of the distance-time, are presented in Figure 6. The bold line shows the trajectory of the wave pattern. Quasi-periodic perturbation moves to the east-northeast at a speed of 90m/s.

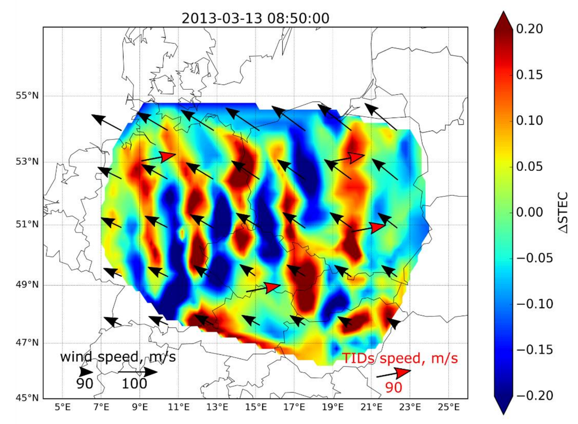


Fig. 4. Maps of STEC over Central Europe at $08^h\ 50^m$, March 13, 2013.

These figures may be interpret as a propagation in the ionosphere of the quasi wave disturbance at a speed of about 90 m/s for more than half an hour and with an average spatial period of about 170 km. These parameters are consistent with the theoretical and experimental results available in literature.

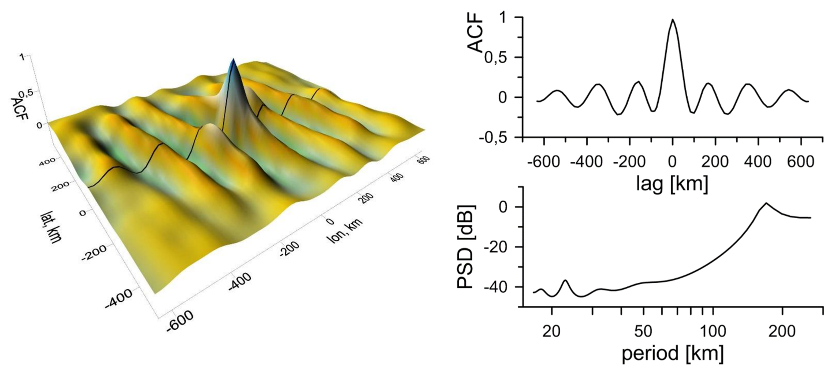


Fig. 5. Spatial autocorrelation function of STEC variations on March 13, 2013 at $08^h\ 50^m$ (left), and its profile along the propagation direction and the spectrum (right).

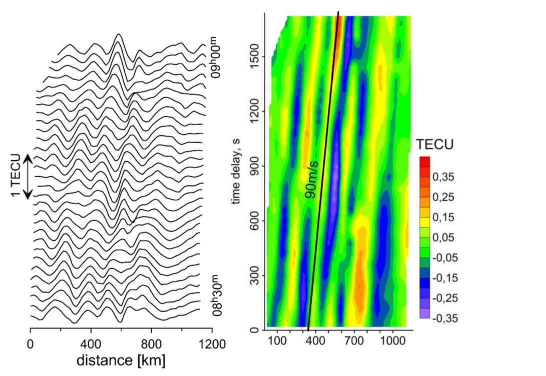


Fig. 6. Profiles of STEC variations along the 52° parallel from 08^h30^m to 09^h00^m on March 13, 2013, Quasi-periodic perturbation moves to the east-northeast with a speed of 90m/s.

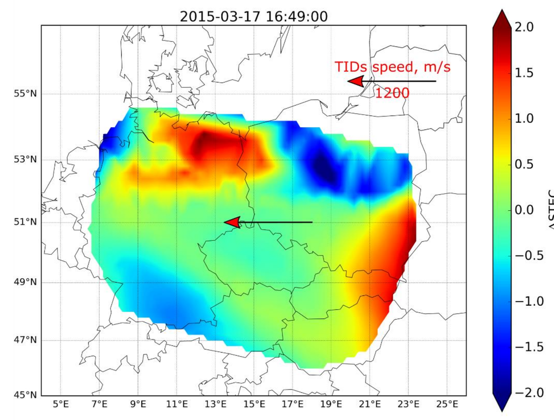


Fig. 7. Extreme variations of TEC in the latitude range near 52°N-54°N at the main phase of the ionospheric storm $16^h\ 49^m$, March 17, 2015.

Maps obtained with Central European sites during strong (Kp=8) geomagnetic storm at the day of St. Patrick in 2015, were analyzed. Disturbances in the main phase of the storm (from 16^h to 18^h on March 17, 2015) are characterized by significant variations of STEC, which were two orders of magnitude greater than at the quiet days. The speed of registered disturbance moves amounted to 1200 m/s (Fig. 7), and was significantly greater then speed of sound at ionospheric heights. Thus, the effect of moving is the most likely linked to the spatial and temporal changes in the flow of the ionizing factor, which is formed in larger quantities, compared to the quite ionosphere conditions. On the other hand, it should be mentioned, that disturbances are located in latitudes range near 52°N-54°N and therefore may be interpreted as the result of electrons precipitation from the Van Allen inner radiation belt, partially destroyed during geomagnetic storm. Time range from 16^h35^m to 17^h00^m (Fig. 8) was chosen due to relative stability of the form of spatial structure. At the rest of the main phase of the storm, the structures remained relatively stable for a maximum of units of minutes. For comparison, results obtained for the lighter storm on March 17, 2013 are presented (Fig. 9).

Map of STEC variations over Central Europe

Fig. 8. From $16^h\ 35^m$ to $17^h\ 00^m$, March 17, 2015.

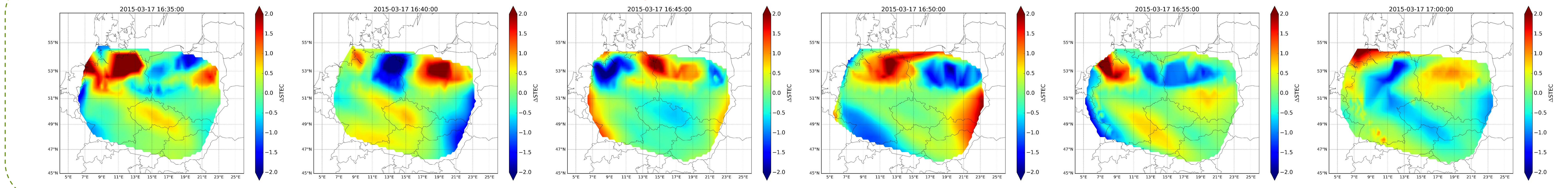
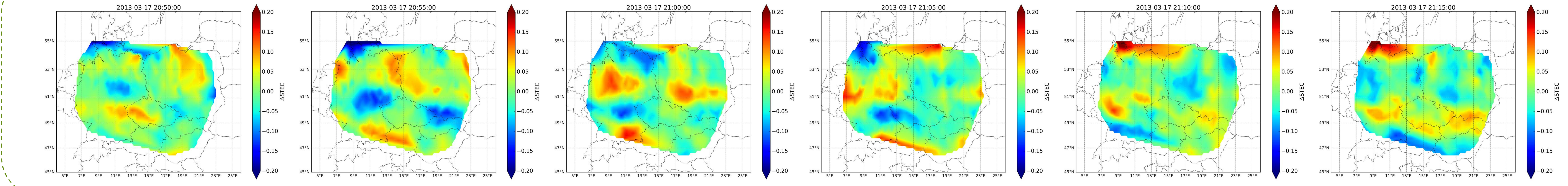


Fig. 9. From $20^h\ 50^m$ to $21^h\ 15^m$, March 17, 2013



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- *GKU Bratislava for the data from SKPOS network.*
- *Polish Head Office of Geodesy and Cartography for the data from ASG-EUPOS.*

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Summary

The Military University of Technology (Warsaw, Poland) in collaboration with the Department of Radiophysics of Geospace of Institute of Radio Astronomy NAS (Kharkiv, Ukraine) developed a new technique of the orthogonal projection of variations of electronic content of the ionosphere (OPVECI) for the mapping of the total electron content, which allows for visualization of the ionospheric irregularities. On the base of data from several nation-wide GNSS- networks in Central Europe in quiet and disturbed geomagnetic conditions, we detected traveling ionospheric disturbances, modeled and measured their parameters, such as direction and speed of movement and the spatial period. TIDs were detected regularly, up to several times a day and were observed within time periods from a few tens of minutes to hours. The directions of movement in most cases were opposite to direction of the horizontal wind at the height of maximum of F2 ionospheric layer. Disturbances during the main phase of the storm on March 17, 2015, were characterized by variations of TEC, two times greater than during the quiet days. It should be kept in mind, that disturbances were located in latitudes range near 52°N-54°N and may be the result of electrons precipitation from the Van Allen inner radiation belt.

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