"Physics of Auroral Phenomena", Proc. XLII Annual Seminar, Apatity, pp. 32-35, 2019

DOI: 10.25702/KSC.2588-0039.2019.42.32-35

OCCURRENCE OF TEC FLUCTUATIONS AND GPS POSITIONING ERRORS OVER EUROPE DURING GEOMAGNETIC DISTURBANCES ON 4 AND 9 NOVEMBER 2018

I.I. Shagimuratov[1], S.A. Chernouss[2], I.V. Despirak[2], M.V. Filatov[2], I.I. Efishov[1], N.Yu. Tepenitsyna[1], G.A. Yakimova[1], S.V. Pilgaev[2]

[1]*WD IZMIRAN, Kaliningrad, Russia*
[2]*Polar Geophysical Institute, Apatity, Russia*

Abstract. In this report we analyzed the occurrence of GPS fluctuations during moderate geomagnetic storm on 4 - 5 November and during minor geomagnetic disturbances on 9 November 2018, as well as their impact on the performance of the satellite navigation system. Despite the low intensity of the disturbances these events caused serious disruptions in the operation of global navigation satellite systems (GNSS) at the high latitudes. We analyzed the similarities and differences in the occurrence of the TEC fluctuations and positioning errors for two periods of disturbances. The positioning errors were determined using the GIPSY - OASIS software. We found rather good similarity between the intensity of the TEC fluctuations and positioning errors.

Introduction

The irregularities of electron density, presented in the high latitude ionosphere, may be caused phase and amplitude fluctuations (scintillations) of the GPS signals [*Aarons et al*., 2000; *Cherniak et al*., 2015]. The intensity of fluctuations increases during geomagnetic storms and substorms. A strong ionospheric fluctuations of GPS signals were registered in the auroral oval and were associated with the auroral disturbances [*Chernouss et al.*, 2015].

In recent years, much attention has been paid on the impact the geomagnetic disturbances on the Precise Point Positioning [*Jacobsen and Andalsvik*, 2016; *Shagimuratov et al*., 2015, 2018] The direct comparison between the intensity of fluctuations and the positioning errors at the auroral stations shown that the accuracy of the point positioning precise at high latitudes was worse during substorms.

In most works the occurrence of the ionospheric fluctuations as well as the positioning errors are concerned with severe storms. In this work we presented the response to moderate and minor storms which observed on 4 and 9 November 2018. We considered the similarities and differences of the occurrence of TEC fluctuations and positioning errors in the auroral ionosphere over Europe for these two events.

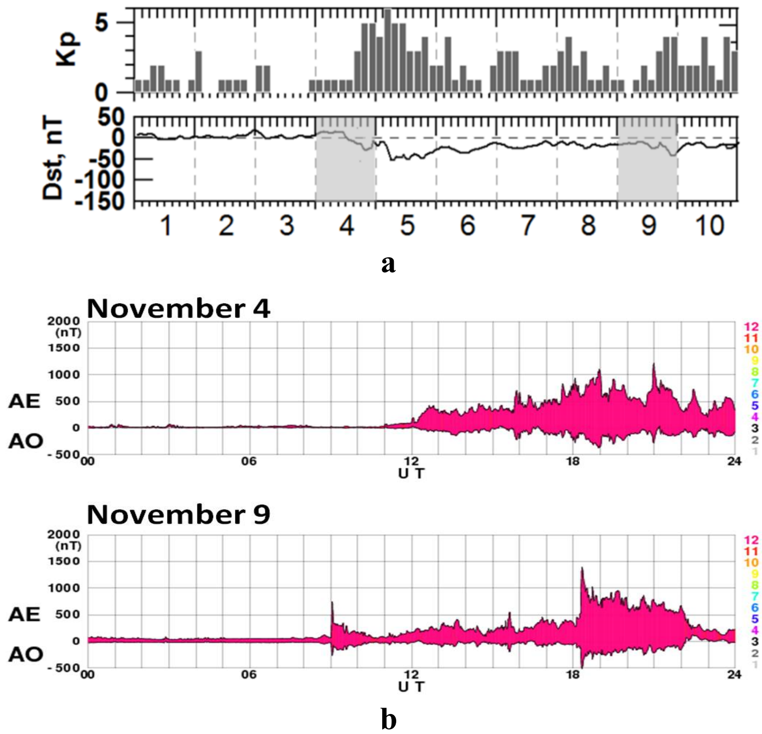

Figure 1. Variations of Kp and Dst indices in the period from 1 to 10 November 2018 (***a***) and variations of AE index for 4 November and for 9 November (***b***).

Data

Fig. 1a shows the variations of Kp and Dst indexes during time period from 1 to 10 November 2018. The first disturbance started on 4 November 2018. The active period started on the second day - on 5 November- and lasted all day. On 9 November the disturbances were short and occurred on the recovery phase of storm.

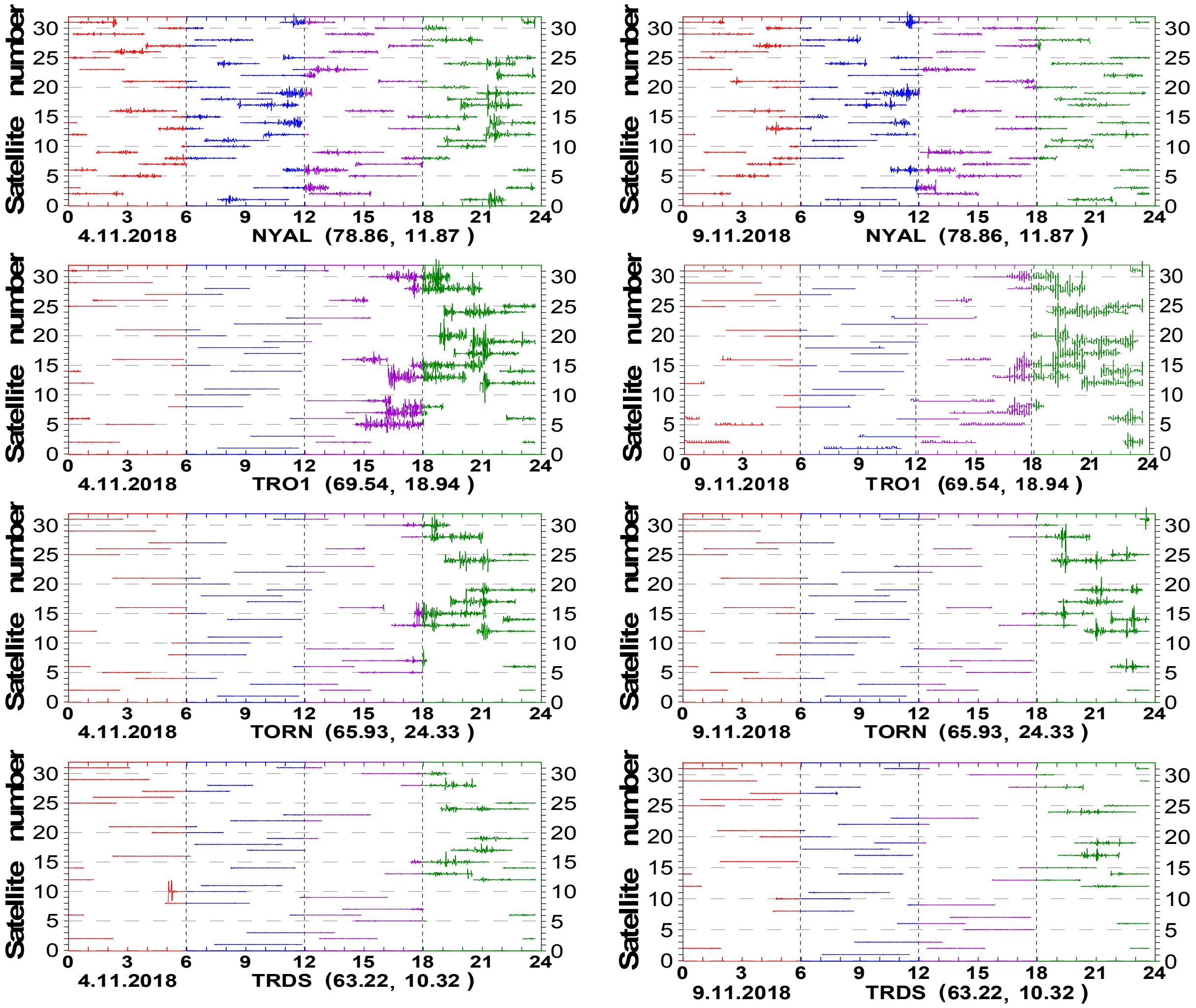

Figure 2. Development of TEC fluctuations (ROT) at different stations during November 4 (*at the left*) and during November 9, 2018 (*at the right*).

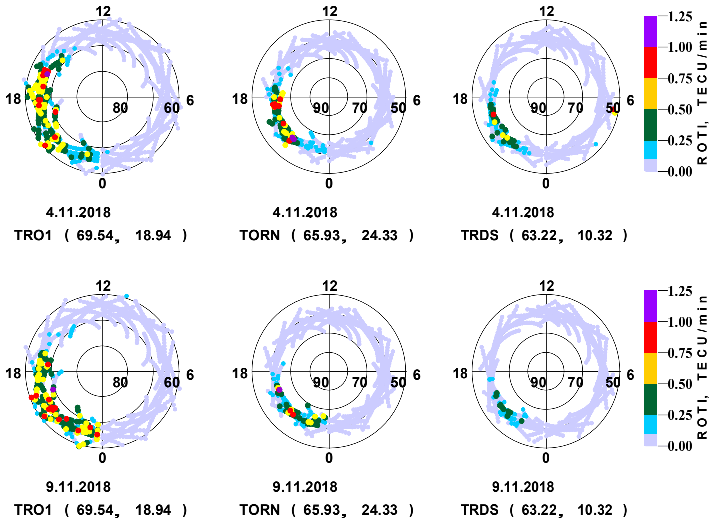

Figure 3. ROTI distributions at different stations on November 4 (*top panel*) and November 9, 2018 (*bottom panel*).

Fig. 1b shows the auroral activity on 4 and on 9 November 2018. It is seen that the development of the auroral activity was rather similar for both storms. On 4 November 2018 the auroral activity started after 12 UT and then gradually increased. Two local maximums took place around 19 and 20 UT. On 9 November the auroral activity sharply roses after 18 UT. So, the auroral activity was observed over Europe in the night time, around magnetic midnight and in this time was often registered the ionospheric fluctuation activity.

Result and discussion

We analyzed the temporal occurrence of the TEC fluctuations using the standard 30 seconds GPS phase measurements of RINEX format files. We evaluated the fluctuation activity by ROT (the rate of TEC) at 1 min interval. On their base is formed the picture (Fig. 2), which demonstrates the behavior of the ROT over single station for all satellite passes on 24-hour interval. We analyzed the latitudinal behavior of the TEC fluctuations using GPS stations, which were located in the auroral and subauroral zones. It is seen that the temporal occurrence of TEC fluctuations during 4 and 9 November is similar, moreover, it associated with the time of development of auroral activity (Fig. 1).

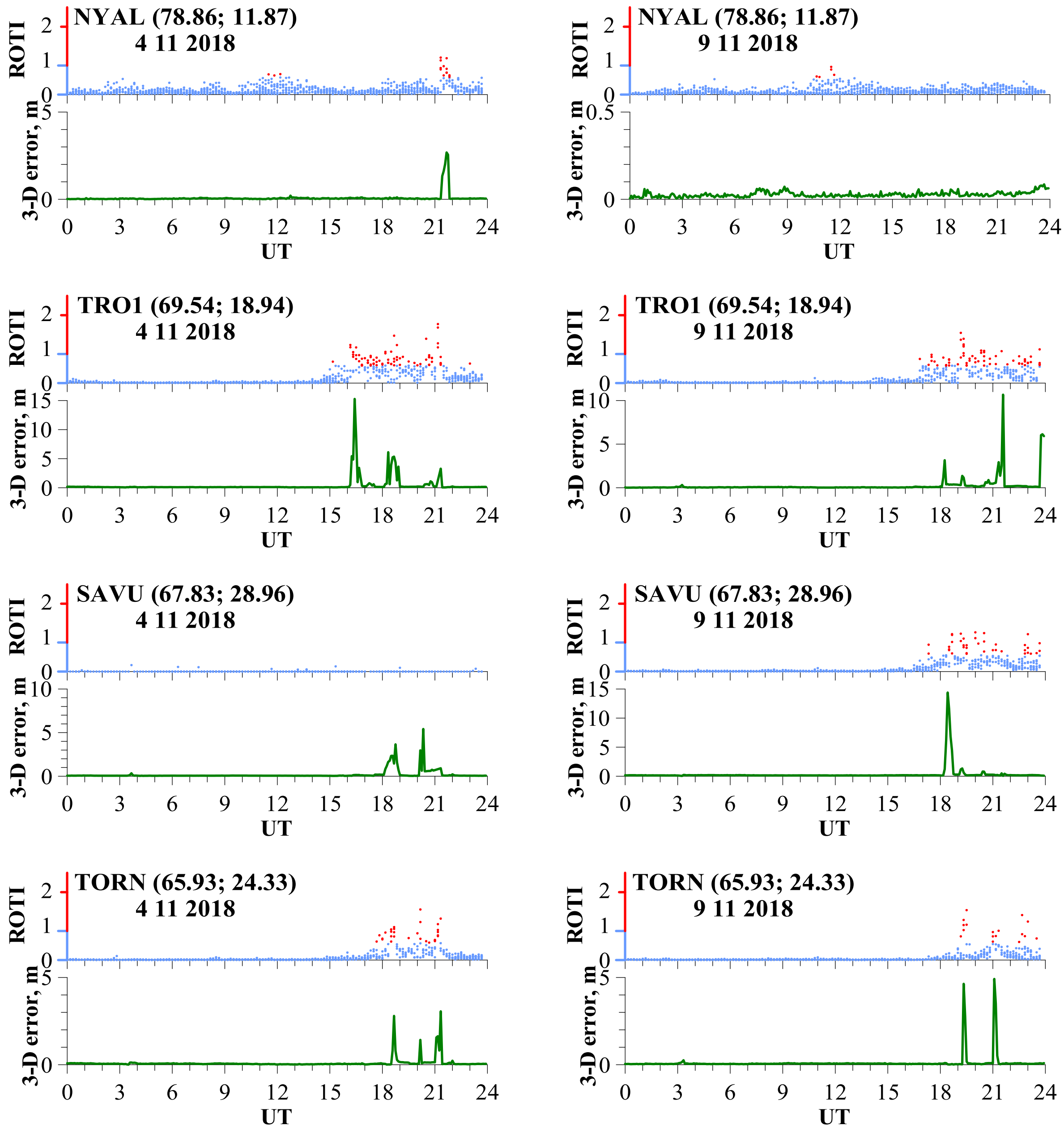

Figure 4. The intensity of the TEC fluctuations (ROTI) and 3D positioning errors at different European stations during November 4 (*at the left*) and during November 9, 2018 (*at the right*).

As a measure of the intensity of fluctuation activity was used the rate of TEC Index (ROTI) based on the standard deviation of the ROT. Index ROTI was estimated by 10-minute interval. For obtain the spatial and temporal distribution of the TEC fluctuations it being formed ROTI images in Corrected Geomagnetic Latitude (CGL) and magnetic local time (MLT) (Fig. 3). As seen in Fig. 3, the maximal intensity observed on the station TRO1, in the period of increasing of the auroral activity. The intensity of fluctuations decreases with increasing of the latitude. The time span of the fluctuations occurrence also decreases with increasing of the latitudes. At lower latitudes stations the fluctuation activity is concentrated near the magnetic midnight.

We analyzed the link between the intensity of TEC fluctuations (index ROTI) and Precise Point Positioning (PPP) errors using the GIPSY software of the NASA Jet Propulsion Laboratory in the kinematic mode (*http://apps.gdgps.net*). The 3D position errors were computed with 5-min interval on the base this software. The 3D position error (P3D) defined as the offset of the detrended coordinate from its median value (x_0, y_0, z_0) and it calculated for each epoch

$$P_{3D}(i) = \sqrt{(x(i) - x_0)^2 + (y(i) - y_0)^2 + (z(i) - z_0)^2} .$$

As median value (x_0, y_0, z_0) was used the coordinate calculated on 24-hour interval for previous day of the storm. We analyzed the link between ROTI and the 3D position errors for stations, located at auroral and subauroral zones, during 4 and 9 November 2018. We analyzed the link between ROTI and the 3D position errors for stations, located in the auroral and subauroral zones during 4 and 9 November 2018. Fig. 4 shows the temporal variations of the ROTI and the 3D positioning errors obtained for auroral and subauroral stations. We can see the very good similarity in the behavior of ROTI and positioning errors, with increasing of values ROTI increases the positioning error at discussed stations. A time behavior of positioning errors is very similar for both considered event of disturbances. It is seen that maximal errors took place at TRO1 station, where they reached more than 10 m. On lower latitudes errors decreased as well as the intensity of fluctuations.

The picture demonstrates the nonlinear character of position errors with respect to changes of ROTI. At NYAL station during 4 November a navigation errors were small, at the same time the errors were below the background. Noted that the NYAL station located at the polar edge of the auroral oval during discussed quiet conditions, while during geomagnetic disturbances it was located in the cusp. As known, TEC fluctuations are ordinary weak in the cusp at the night.

Summary

We analyzed the occurrence of the TEC fluctuations and the positioning errors associated with auroral disturbances over Europe during 4 and 9 November 2018. It is shown that these disturbances were registered at the evening time and the maximal intensity of the TEC fluctuations took place in the auroral ionosphere, while the weak fluctuations were observed in the subauroral zone. We related these effects with the dynamics of the auroral oval. We have also analyzed an impact of the geomagnetic disturbances on the Precise Point Positioning errors, which we determined by the GIPSY-OASIS software (APS-NASA). It is shown that more weakly storm, on 9 November 2018 (Kp index ~ 4) caused strong positioning errors of GNSS Navigation system, than more strong storm on 4 November 2018.

Acknowledgment. This investigation was supported by RFBR Grants № 19-05-00570 (Shagimuratov I. I.) and № 17-45-510341(Filatov M.V.) The authors are grateful for GNSS data provided by IGS/EPN.

References

Aarons J., Lin B, Mendillo M., Liou K., Codrescu M. (2000). Global Positioning System phase fluctuations and ultraviolet images from the polar satellite. *J Geophys. Res. Space*. 105(A3), 5201–5213. DOI: 10.1029/1999ja900409.

Cherniak Iu., Zakharenkova I. and Redmon J. (2015). Dynamics of the high-latitude ionospheric irregularities during the 17 March 2015 St. Patrick's Day storm: Ground-based GPS measurements. *Space Weather*. 13, 585 – 597. DOI: 10.1002/2015SW001237.

Chernous S.A., Shvets M.V., Filatov M.V. et al. (2015). Studying navigation signal singularities during auroral disturbances. *Russian Journal of Physical Chemistry B*. 9(5), 778 — 784.

Jacobsen K., Andalsvik Y. (2016). Overview of the 2015 St. Patricks day storm and its consequences for RTK and PPP positioning in Norway. *J. Space Weather Space Clim*. 6(A9). DOI:10.1051/swsc/2016004.

Shagimuratov I.I., Chernous S.A., Cherniak Iu. et al. (2015). Phase fluctuations of GPS signals associated with aurora. *Proc. 9th European Conf. on Antennas and propagation (EuCAP)*, Lisbon, 12-17 April 2015, paper 1570053943.

Shagimuratov I.I., Chernouss S.A., Despirak I.V. et al. (2018). Occurrence of TEC fluctuations and GPS positioning errors at different longitudes during auroral disturbances. *Sun and Geosphere*. DOI: 10.31401.