"Physics of Auroral Phenomena", Proc. XXXIII Annual Seminar, Apatity, pp. 151 - 154, 2011

Polar Geophysical Institute

CONJUGATE AND INTER-HEMISPHERIC OCCURRENCE OF GPS TEC FLUCTUATIONS IN HIGH LATITUDE IONOSPHERE

I. Shagimuratov[1], S. Chernouss[2], I. Ephishov[1], N. Tepenitsyna[1], and L. Koltunenko[1]

1. *West Department of Institute of Terrestrial Magnetism, Ionosphere and Radiowaves Propagation, Kaliningrad, Russia*
2. *Polar Geophysical Institute KSC RAS, Apatity, Murmansk region, Russia*

Abstract. In the given report we present storm-time effects of TEC fluctuations in the polar ionosphere and discuss the similarities and differences of some features of their development in northern and southern hemisphere using GPS measurements at the geomagnetic conjugated stations. In paper relation between TEC fluctuations occur and auroral oval parameters are discussed

Data source

GPS observations carried at the Antarctic and Arctic IGS stations were used to study the development of TEC fluctuations in the high latitude ionosphere In Table1 the geomagnetic conjugated stations and their geographic and Corrected Geomagnetic coordinates use in this study are presented.

Stations	Geographic Coordinates		Corrected Geomagnetic Coordinates	
	latitude	longitude	latitude	longitude
MCM4	-77.50	166.40	-79.99	322.95
RESO	74.41	-94.53	83.10	320.28
MAC1	-54.30	158.56	-64.18	247.29
FAIR	64.58	-147.30	64.95	264.67
WHIT	60.45	-135.13	63.29	278.64
KERG	-49.21	70.15	-58.29	123.33
JOEN	62.23	30.05	58.36	108.44
DAV1	-68.34	77.58	-74.67	102.29
NYAL	78.55	11.52	75.77	111.78

Table 1. Geographic and corrected geomagnetic coordinates of Antarctic and Arctic IGS stations

Estimation technique

For the analysis of TEC fluctuations we used high-precision dual-frequency GPS phase measurements of individual satellites passes. As measure of phase fluctuation activity we used the rate of TEC (ROT) on 1 min interval:

$$ROT = 9.53\cdot((\Phi1 - \Phi2)t_{i+1} - (\Phi1 - \Phi2)t_i)$$

where $\Phi1$ and $\Phi2$ [m] denote the measured differential carrier phase observable of L1 and L2. A scaling factor 9.53 converts the differential ionospheric delay to units of electrons/m2. The rate of TEC characterizes relative spatial changes of TEC along satellite passes. When using ROT we avoid the problem of phase ambiguities.

As a measure of TEC fluctuation activity we used also the Rate of TEC Index (ROTI) based on standard deviation of ROT:ROTI has been estimated at 10-min interval

.

Data and analysis

Some authors studied the dependence of the TEC fluctuations on the magnetic and auroral activity mostly during great planetary storms (Shagimuratov, 2008; Afraymovich and Perevalova 2006; Aarons et al., 2000). This method of attack was applied because planetary storms produce affects on GPS signals not only in high but also in middle latitudes. Our paper devoted to the conjugacy of these phenomena**.** Fig. 1 (a,b,c) presents the development of TEC fluctuations during the geomagnetic activity period of 23-27 July 2004. Pictures illustrate the occurrence of TEC fluctuations for all satellite passes observed over a 24 hour interval. At all stations located at different longitude occurrence TEC fluctuations took place at the same UT. The intensity of fluctuations essentially increases during active phase of storm. Maximal effect was observed while Bz was negative. At polar stations MCM4 and RESO intensity TEC fluctuations are differed, it is probably season effect. At auroral stations MAC1/FAIR the storm-time development TEC fluctuations is rather similar At subauroral stations KRG/JOEN TEC fluctuations are clearly seen during the most disturbed days, when Bz is strong negative. The picture of TEC fluctuations at both hemispheres was very similar. The TEC fluctuations are caused by the presence of medium and large-scale irregularities in the ionosphere. To evaluate the intensity of TEC fluctuations and accordingly the ionospheric irregularities we used the index ROTI. As well as auroral oval the spatial and temporal occurrence of the irregularities can be visually presented in coordinates- Geomagnetic local time and Corrected geomagnetic latitude. As example Fig. 2 shows the pictures of TEC fluctuations over polar cap geomagnetic conjugate stations of MCM4/RESO and auroral stations DAV1/NYAL for quiet day of 21 July and the most disturbed day of 27 July 2004.

In the figure it is clearly seen that during the quiet day intensity and number of irregularities are low against to the disturbed day. The picture demonstrate that similar to auroral oval we can speak about irregularity oval (Aarons, 1997)

Relation between irregularities oval and auroral ovals

As we know that auroral ovals are conjugated (Feldstein et al, 1973) we can suppose conjugancy of irregularities oval too. We should just to know relationship between different ovals. Distribution of numbers of TEG fluctuations have oval symmetry too (fig. 2). Lets see as a sample the measurements of TEC fluctuaton at Antarctic stations and compare that with the auroral oval from (Zverev V.L., Starkov G.V. 1975) for events 6-10.10.2004.

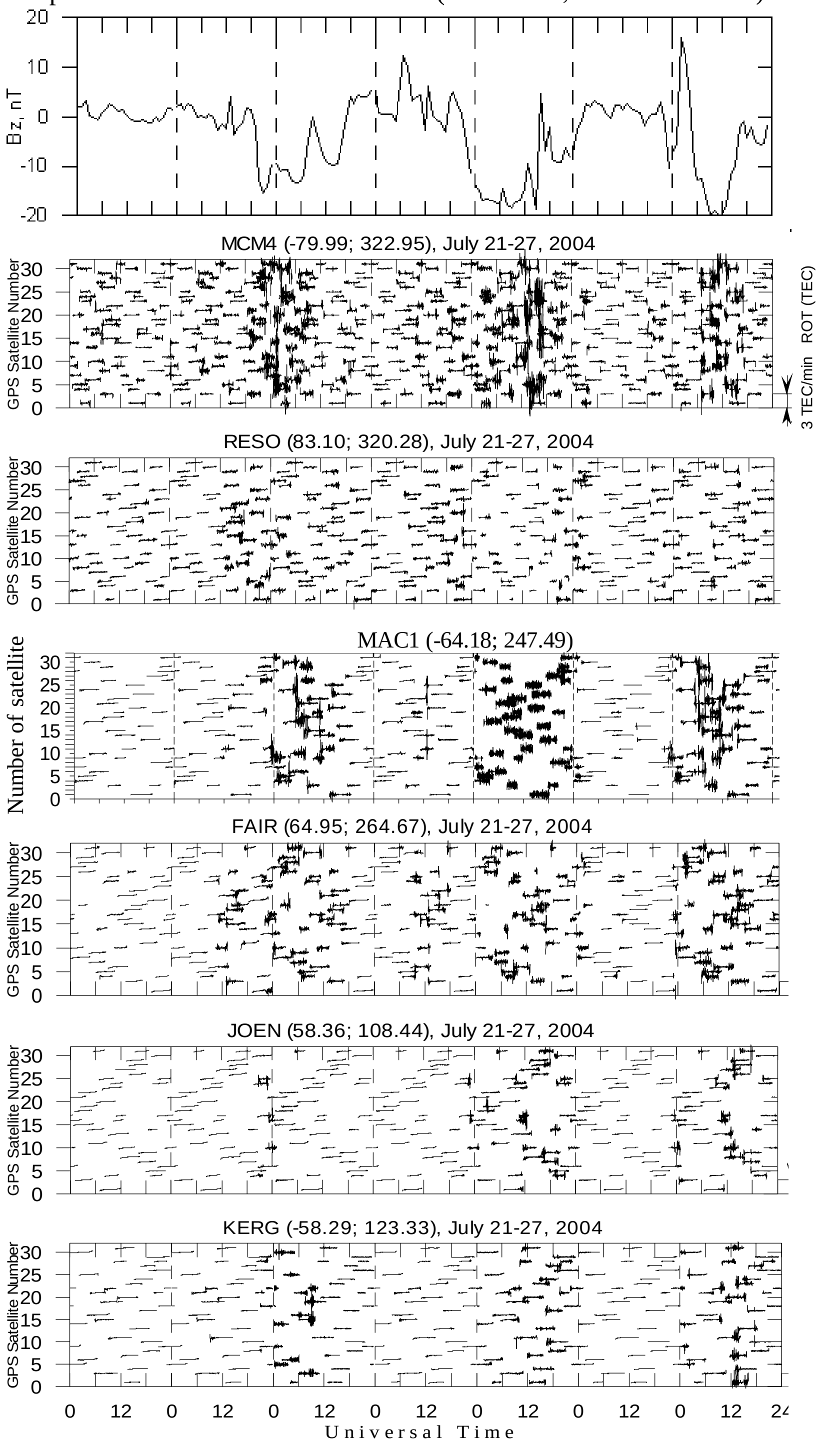

Fig 1. a) Variations of Bz and TEC fluctuations occurrence over geomagnetic conjugated polar cap stations MCM4 (south) – RESO (north). b) TEC fluctuations occurrence for auroral MAC1 (south) – FAIR (north) stations. c) Subauroral JOEN (south) – KERG (north) stations.

The Antarctic GPS-data shows strong TEC fluctuations observed at the Antarctic stations CASI, DAVI and MCM4 of 6-10 November, 2004 (Fig. 3). These fluctuations have been associated in (Shagimuratov et al, 2006) with large-scale ionosphere irregularities and polar patches in TEC. We consider that these phase fluctuations could relate directly to electron density irregularities inside the auroral oval. It is perfectly shown in (Aarons et al, 2000) through a similar dependence of the auroral activity and TEC on the magnetic storms development. It is also confirmed by the comparison of the aurora distribution in the oval (Feldstein et al, 1974, Zverev and Starkov 1975) and the TEC measurements by GPS-receivers (Shagimuratov et al, 2006). To understand the dependence in the case considered, we show the oval features by the azimuth diagrams presented in Fig. 5a,b. The diagrams are obviously similar because there are the day-night asymmetry in spatial distribution of the number of phase fluctuations (Fig. 4) and the similar asymmetry in the distribution of the areas covered by the auroral oval in a case study. The maximum number of fluctuations is concentrated near the midnight sector of the oval, where it has maximum thickness. The circular azimuth diagrams show a normalized distribution of the fluctuation number in 30° sectors (Fig. 5a) and the normalized areas occupied by the auroral oval in the same sectors (Fig. 5b). This picture is much better for comparison of auroral and TEC ovals because a different position of both ovals in latitude does not count.

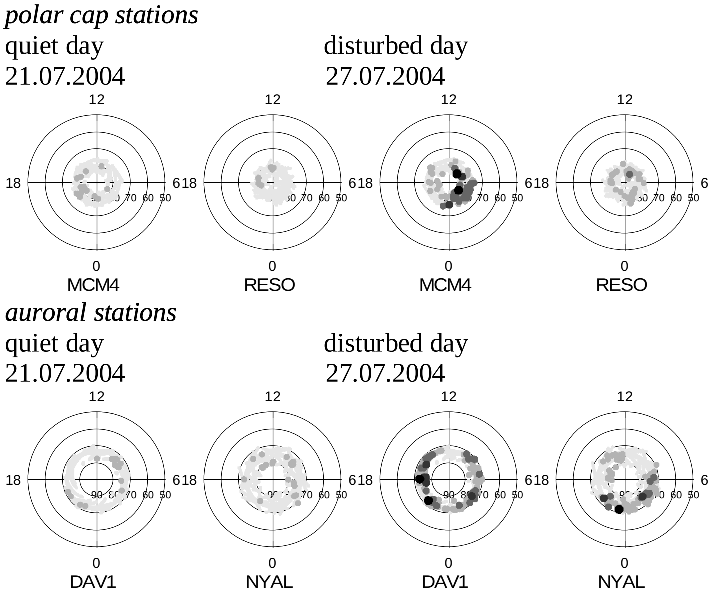

Fig. 2. Spatial and temporal distribution of TEC fluctuation in geomagnetic local time and Corrected Geomagnetic Latitude using GPS measurements of 19 IGS stations. The pictures show the dynamics of the irregularity oval during quiet and disturbed conditions (Northern hemisphere) on 24 hour interval.

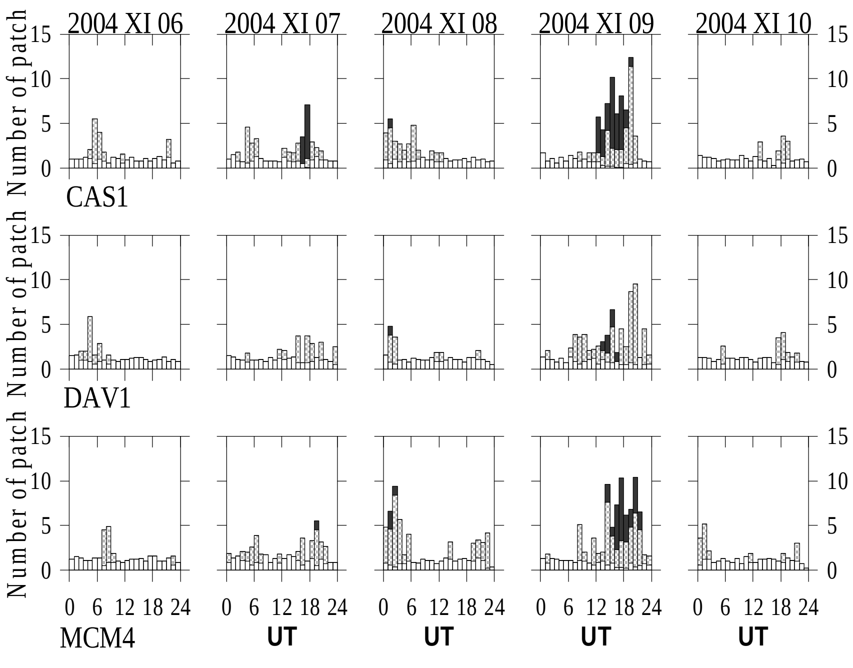

Fig. 3. Diurnal variations of patch activity at different Antarctic stations over November 6-10, 2004.

Primary images of the auroral oval for the azimuth vector diagram were produced by the data described in (Feldstein at al., 1974; Zverev and Starkov 1975), which are based on the dependence of the oval parameters on the geomagnetic activity. The similarity between both diagrams is obviously, therefore one can see the valuable role of the auroral oval position for the events observed in the phase fluctuations and in the ionosphere irregularities, which can have adverse effects on communication and navigation systems. Normalized azimuth distribution of aurora inside the auroral oval and patches in TEC show a good similarity. This is because the GPS ray path trajectories are larger disturbed and worse fitted for working satellites pass through the area of the ionosphere with the auroras and the GPS-receiver signal violations.

a **b**

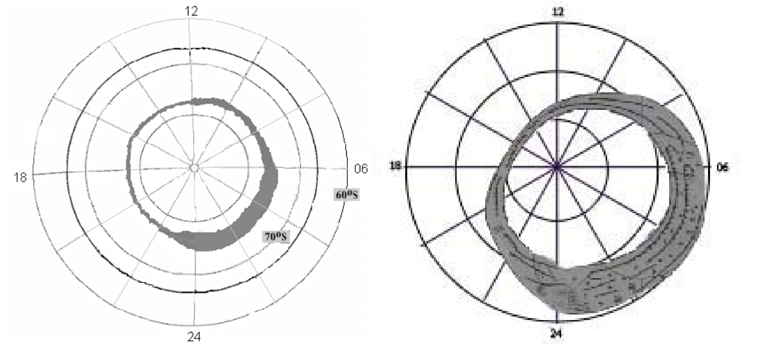

Fig. 4. a) TEC fluctuations azimuth distribution at Antardtic stations at ~ 18 UT; b) Auroral oval over Antarctica at Q = 6.

a b

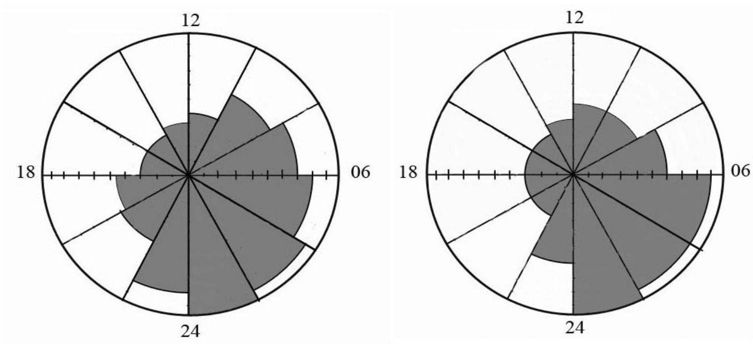

Fig. 5. a) Normalized vector azimuth diagram of the number of ionospheric irregularities (TEC patches) occurred inside 30º sectors (the sector radius is proportional to the number of TEC patches). b) The diagram of the areas covered by the auroral oval in the 30º sector (the sector radius is proportional to the area square).

Conclusions

The GPS measurements of northern and southern hemispheres were used to study storm-time development of TEC fluctuations at conjugate area in polar cap, auroral and subauroral ionosphere. During storms the intensity of irregularities essentially increases and strong TEC fluctuations can be registered at subauroral ionosphere. Maximal activity of TEC fluctuations took place when IMF Bz component was large negative. Storm-time development of TEC fluctuations caused by ionospheric irregularities was controlled by UT. At polar cap stations TEC fluctuations more expressed at southern (winter) hemisphere. Over auroral and subauroral stations the difference of TEC fluctuations occurrence was less expressed. Auroral oval presentation as azimuth vector diagrams could be used for a study of GPS signals propagation.The GPS technique can be effectively use for probing of the oval irregularities of high-latitude ionosphere near real time and auroral technique can be used for control of GPS signal.

Acknowledgements. The authors thanks to O.Antonenko for preparation work and to the Research Council of Norway through the project named: Norwegian and Russian Upper Atmosphere Co-operation on Svalbard part 2 #196173/S30 (NORUSCA2), the Nordic Council of Ministers grant number i A09161 and the Russian Fund of Basic Research grant 10-05-98800-r-sever_a for the support of this study.

References

Aarons, J., Global positioning system phase fluctuations at auroral latitudes, *J. Geophys. Res.*, 102 (A8), 17219-17231, 1997.

Aarons, J., Lin, B., Mendillo, M., Liou K., Codrescu M., 2000, GPS phase fluctuations and ultraviolet images from the Polar satellite, *Journal Geophysical Research.*, 105, 5201-5213.

Afraymovich E.I., Perevalova N.P., 2006, GPS-monitoring of the Earth`s upper atmosphere, *Irkutsk: SC RRS SB RAMS*, 480 p.

Feldstein,Y.I., Starkov G.V. and Zverev V.L., 1974, Conjugacy of auroral oval. *Proceedings of Antarctic review meeting*, Tokyo, NIPR, pp.29-37.

Shagimuratov I., Efishov I., Ruzhin Yu, Tepenitsyna N., 2006, Storm-time occurrence of TEC fluctuations associated with polar patches using GPS measurements. In *Physics of Auroral Phenomena*, Proceedings of XXIX Annual Seminar, Apatity, Kola Science Centre RAS, pp. 61-64.

Shagimuratov, I.I., I.I. Ephishov, N.Yu. and Tepenitsyna, Similarities and Differences of storm time occurrence of GPS phase fluctuations at northern and southern hemispheres, *In Proceeding EUCap* 2009.

Zverev V.L., Starkov G.V. 1975. Synoptic maps of the auroral oval in the South Hemisphere. In *Antarctic*, 14, *Nauka*, Moscow, pp. 5-33 (in Russian).