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RESPONSE OF THE IONOSPHERE TO MODERATE GEOMAGNETIC STORM AT LOW SOLAR ACTIVITY

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Abstract. In this report we present an analysis of TEC response to moderate (Dst¡70 nT), 11 October 2008, geomagnetic storm using GPS observations of European network. Strong short-term positive effect was detected near noon. The TEC enhancement exceeded 100% on latitudes of 65-35°N and was decreased to lower latitudes. The positive effect was associated with large scale traveling disturbance. During storm there was observed the increase and modification of horizontal gradients structure and ionospheric trough had moved to equator, until 57°-58° geomagnetic latitudes.

1 INTRODUCTION

Geomagnetic storms cause strong changes in ionosph Ann.Geophis., 27, 1605-1612, (2009)ere. During storm the horizontal gradients and scintillations of GPS signals increase. Irregular ionospheric gradients can complicate the phase ambiguities resolving and as consequence will worse the accuracy of GPS positioning. Storm-time geomagnetic conditions may influence also on the estimation of satellite/receiver biases. Rapid phase and amplitude scintillations lead to degrade GNSS network performance[1].

In last years the numerous works with using GPS TEC measurements to study ionospheric storm effects during high solar activity were presented. In this paper we analyze the occurrence of moderate geomagnetic storm on 11 October 2008 over Europe in TEC variations. For analysis of spatial and temporal changes of TEC distribution over Europe TEC maps were created by using GPS observations of EPN network. We discuss the distinctive features of storm-time TEC behavior at low solar activity.

2 DATA

GPS observations collected at IGS/EPN network were employed to reconstruct diurnal variations of TEC using all satellite passes over individual GPS stations. More than 150 stations were included in the analysis of the TEC response to a geomagnetic storm.

In order to obtain the spatial and temporall variation of TEC there were created the TEC maps. The large number of GPS stations in Europe provided a good coverage for GPS data and enable to get high-accuracy TEC maps with an error of 0.5-2 TECU providing TEC maps with a spatial resolution of 100-300 km and temporal resolution of 15 min.

3 OBSERVATION AND DISCUSSION

3.1 Spatial and temporal TEC changes during storm

To study the storm-time development of TEC we produced TEC maps with high spatial and temporal resolution. The dynamics of the spatial distribution of TEC over Europe was analyzed relative to the TEC behavior of previous quiet days. Feature of this storm it was pronounced positive effect occurred near noon. In Figure1 there is presented day time TEC maps over Europe for quiet and first storm days of 10 and 11 November 2008 respectively.

The positive effect started at the begin of the main phase of geomagnetic storm and lasted during driven phase of storm days. At middle latitudes maximal effect took place near noon, the enhancement of TEC was about 100%, this value was weakly decreased to lower latitudes. Note that the positive effect had begun on the east part of Europe then it was moved to west.

The TEC maps demonstrate significant modification of the ionosphere during this moderate storm. In day time the structure of horizontal gradients is noticeably changed in compare with quiet day. TEC gradients were strongly increased and appeared at subauroral latitudes; it was associated with occurrence of the ionospheric trough.

The mid-latitude trough is well recognized on TEC maps as longitudinally extended depression of TEC during evening and night time. The minimal value of TEC took place on trough bottoms during night-time and reached only a few TEC units. On maps it may be seen that the trough occurrence began at 14 UT in east Europe higher than 70°N.

3.2 Dynamics of TEC latitudinal profiles

As one can see TEC maps demonstrate that response of TEC was strongly depended on latitude. The latitudinal TEC profiles were constructed from TEC maps with one-hour interval. Figure 2 presents the storm-time behavior of latitudinal TEC profiles for quiet and disturbed days. During storm the TEC profiles were essentially changed. The TEC enhancement are recognized at day-time profiles during the first day of storm, while at the second day the weak TEC depression (negative effect) took place at all discussed latitudes. The behavior of TEC profiles depends on the trough location. During quiet geomagnetic condition the day-time TEC slowly decreases towards high latitudes, with latitudinal gradients of about 0.10.2 TECU/degree. These values are in agreement with results obtained for period of maximum solar activity2. After noon the TEC profiles

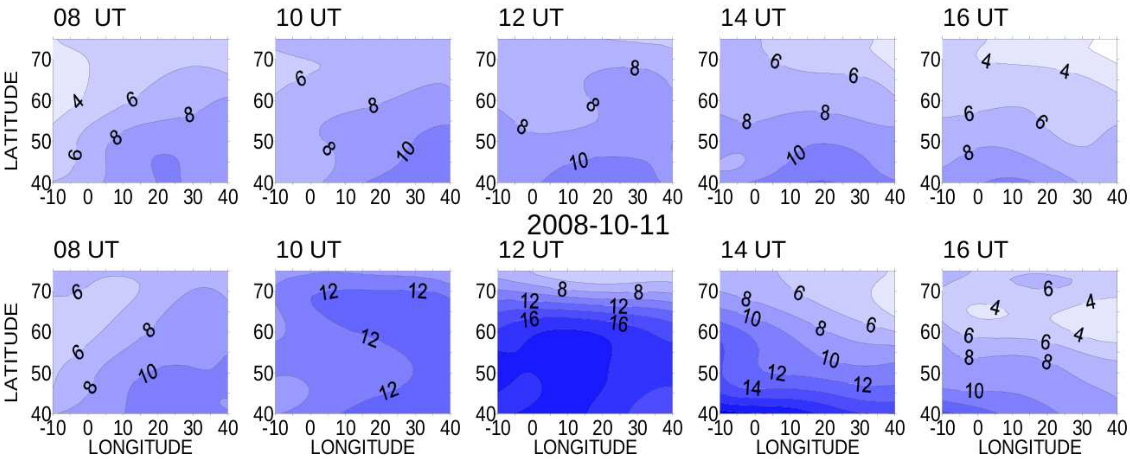

Figure 1: The TEC maps for the disturbed day 11 October and quit 10 October 2008).

represent trough-like structure recognized at latitudes about 65o N. As one can see on Figure 2 the strong TEC gradients are observed at polar and equator walls of the trough. It is interested that strongest gradients took place near 12 UT at latitudes higher than 56°N.

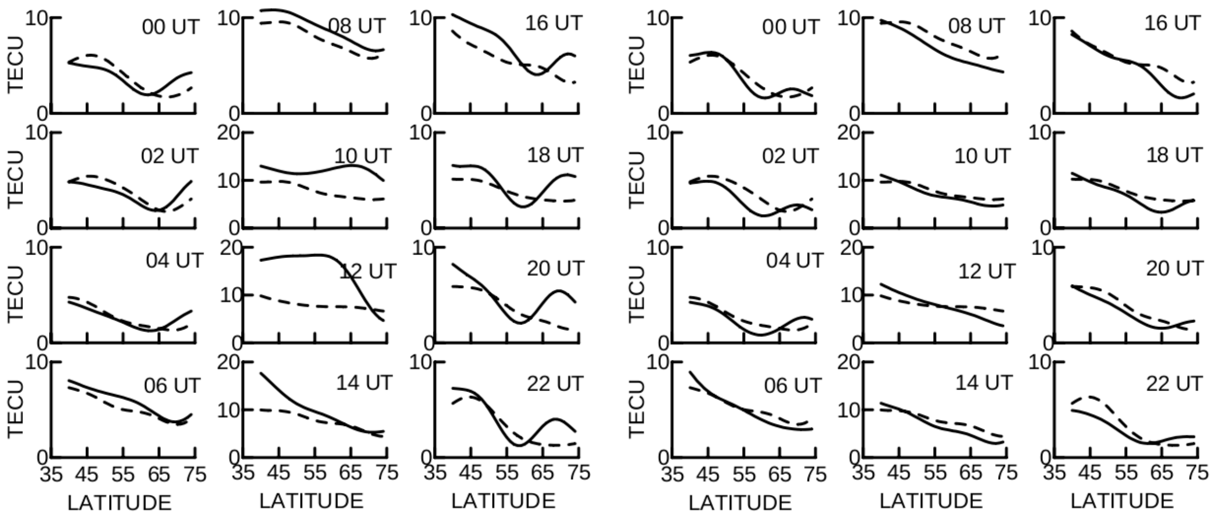

Figure 2: Dynamics of latitudinal TEC profiles during quiet (dashed line) and disturbed days (solid line) of 11-12 October 2008 over Europe at longitude 20 E

3.3 Evolution of diurnal TEC variations

Storm-term evolution of diurnal TEC variations at different latitudes over Europe is presented in Figure 3. It shows the variations of TEC over individual European stations at a latitude range from 70°N (top) to 40°N (down) around a longitude of 20°E. The curves are shifted one after another to 5 TECU. This picture demonstrates the latitudinal occurrence of storm in TEC variations day before, during this disturbance and day after.

Positive effect is developed during active phase of the storm. The increasing of TEC starts in morning at all considered latitudes. Storm effect was lasted less than 12 hours, TEC enhancement prevailed during day time. At next day the weak negative effect took place. Actually, the ionosphere is recovered to pre-storm conditions at next day. The striking surge of TEC enhancement was occurred near 12:30UT. Amplitude of the surge reached factor 2 and slowly decreased to the equator. Figure 3 (right) presents the temporal location of surge in dependence on latitude. It is clearly seen that surges location has some delays from high to low latitudes. It is evident that surge propagates from north to south. It is the occurrence of ionospheric travelling disturbance, the speed of the TID was evaluated about 450-500 m/s. The value is in accordance with results early obtained by Shagimuratov et al.[3], Borries et al.[4].

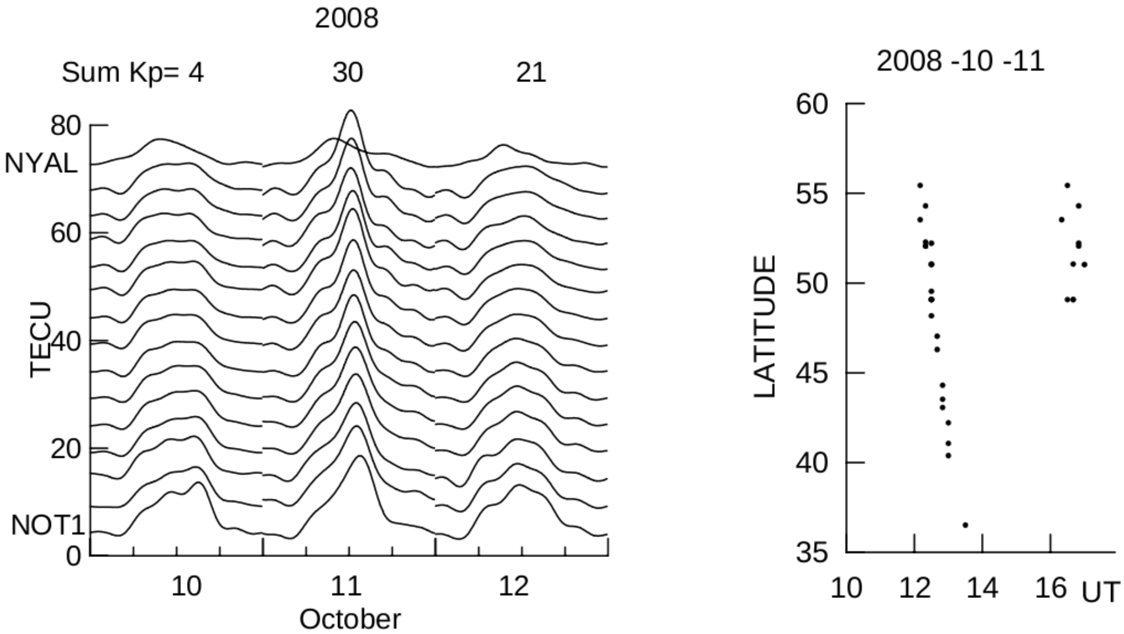

Figure 3: Diurnal variations of TEC over Europe at different latitudes during 10 12 October 2008 (left panel) and location of surge TEC enhancement in depend on latitudes for 11 October (right)

4 CONCLUSION

The distinctive feature of the moderate geomagnetic storms was the short duration ionospheric effect. Strong short-term (about 2 hour) positive effect reached factor 2 relative to undisturbed conditions. This effect was associated with wave process propagated from auroral ionosphere to equator with speed of about 450 m/s. During storm the horizontal gradients were essentially increased in the ionosphere. The disturbance leads to the change of TEC gradients structure in compare with regular gradients observed during quiet ionospheric conditions. Maximal latitudinal gradients took place near equator and polar walls of main ionospheric trough. Analysis of TEC fluctuations occurrence on high latitude stations reveals that auroral oval was moved to 57°N.

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