Multi-instrumental Analysis of the Moderate Ionospheric Storm Occurred at the Background of Low Solar Activity

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Abstract

The ionospheric response to the moderate geomagnetic disturbance which occurred on October 11, 2008 was analyzed with use of the multi-instrumental database. This disturbance occurred during a period of very low solar activity. A relatively weak but isolated geomagnetic disturbance was characterized by the well-pronounced positive effect observed in the ionosphere at the dayside. In the given study we used GPS measurements provided by IGS network, ground-based vertical sounding measurements, JASON-1/JASON-2 altimeter observations, CHAMP PLP and FORMOSAT-3/COSMIC radio occultation measurements.

1. Introduction

Analysis of the ionosphere reaction to geomagnetic activity is still actual topic in space geophysics. Special attention should be focused on the study of the ionospheric storms occurred during low solar activity, e.g. the extended solar minimum of 23/24 solar cycles, when ionosphere was rather poor in density and reacted sensitively to the very moderate geomagnetic disturbances.

The moderate geomagnetic disturbance of October 11, 2008 took place during extended solar minimum of 23/24 solar cycles. Figure 1 illustrates change of the Kp and Dst indices during October 1-20, 2008. The main phase onset of the storm took place on October 11, 2008 after 07.00 UT, when the Dst index changed from 13 nT to negative values. The Dst index reached the minimum value of -60 nT at ~11.00 UT, after that the phase of recovery began. The main phase duration of geomagnetic disturbance was about 4 h, the recovery phase – more than 72 h.

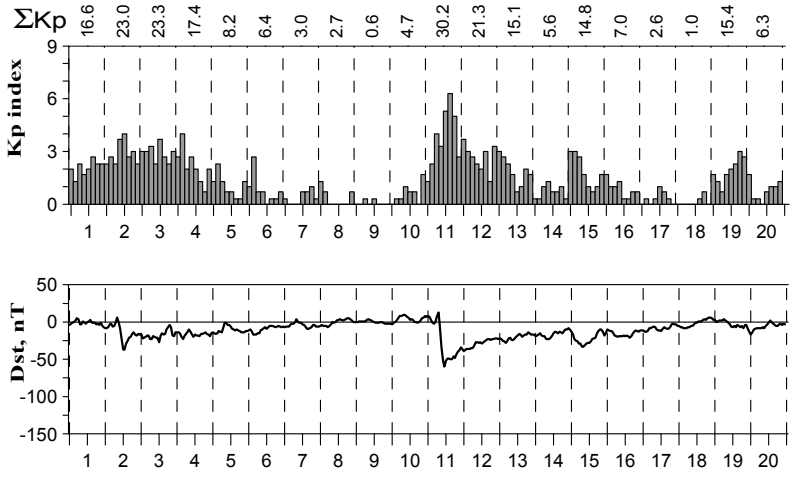

Fig. 1. Variations of Kp and Dst indices during October 1-20, 2008

2. Database and Results

The ionospheric response to the moderate geomagnetic disturbance which occurred on October 11, 2008 was analyzed using the multi-instrumental database of the ground-based and satellite-born observational facilities. We involved into analysis multi-site network of the ground-based stations of the ionospheric vertical sounding, permanent

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network of GPS receivers (IGS), several Low Earth Orbit (LEO) satellite missions – CHAMP, JASON-1,2, FORMOSAT-3/COSMIC.

As a source of global TEC distribution we used IGS Global Ionospheric Maps (GIMs) of TEC in the IONEX format. These data are accessible at the ftp server: ftp://cddis.gsfc.nasa.gov/pub/gps/products/ionex. The GIMs are generated routinely by the IGS community with resolution of 5° longitude and 2.5° latitude and temporal interval of 2 hours; one TEC unit (TECU) is equal 10^{16} electrons/m^2. Figure 2 represents variation of global TEC for different moments of time at October 10 and 11 (quiet vs. disturbed day). It is clearly seen the considerable enhancement of TEC at 12 UT both in the equatorial region and towards to the midlatitudes of the Northern and Southern Hemispheres. At the forthcoming hours the increase of TEC at the equatorial ionization anomaly and low latitudes was well-pronounced at the day-side hemisphere.

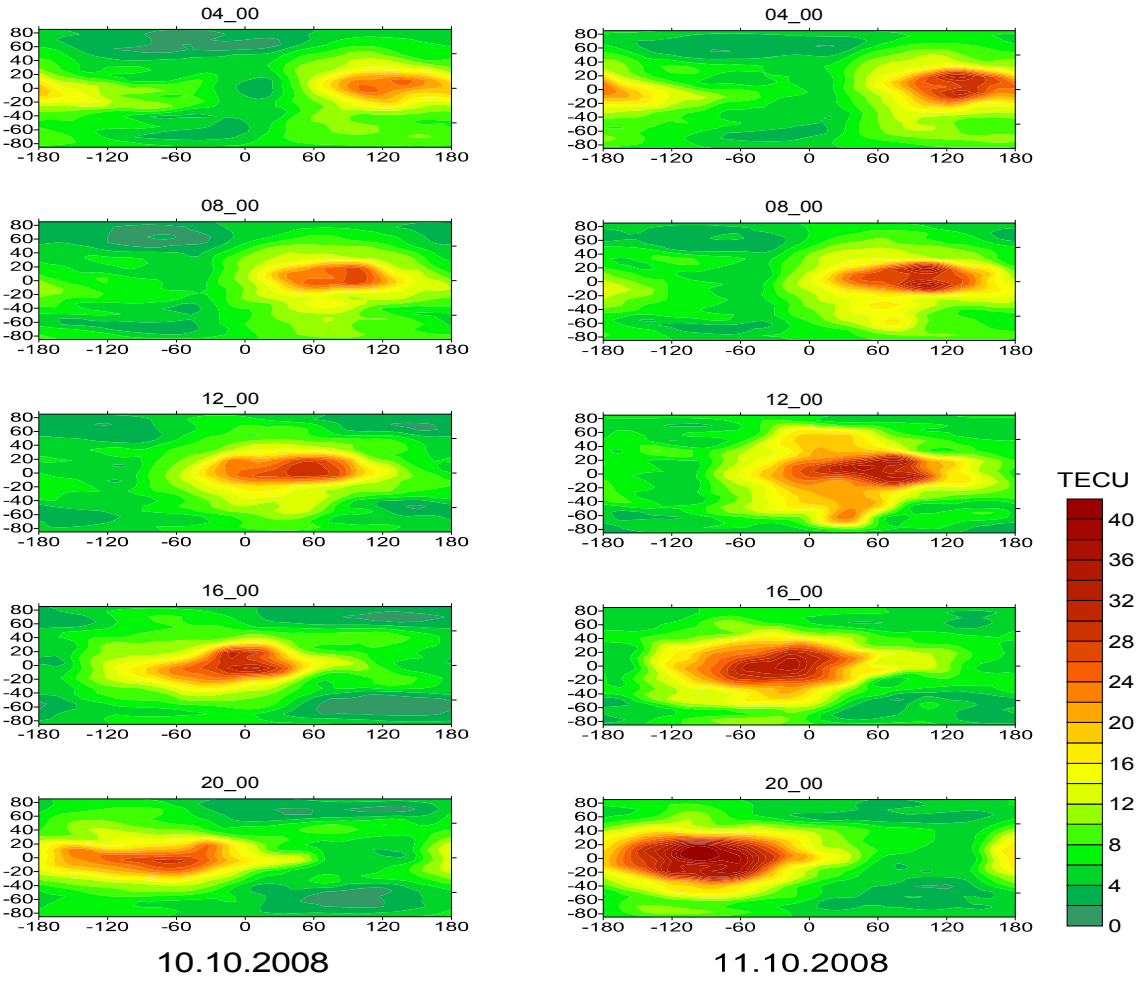

Fig.2. Global TEC maps for different moments of time at October 10-11, 2008

Though Dst decrease during October 11, 2008 storm was not so deep, this disturbance leads to a strong TEC enhancement. Well-pronounced positive effect was observed at European and African midlatitudes during day-time. At middle latitudes of the European region the maximal effect took place near noon, the enhancement of TEC was about 100%. Figure 3 shows diurnal variations of TEC at different latitudes over Europe during October 7-15, 2008. It demonstrates the behaviour of TEC over individual European GPS stations located at the latitude range from 60°N (top) to 40°N (down) around a 13°E meridian. The actual observations are indicated with a solid line and represent the vertical TEC in TECU for GPS stations. For October 11, 2008 the considerable enhancement of TEC reached the factor of 2. This effect was well-pronounced at all stations and has practically the same magnitude for all considered latitudes. The strong TEC increase over European region has rather short duration (11-15 UT) and reached the maximum value of 9 TECU (100% relative to the quiet conditions).

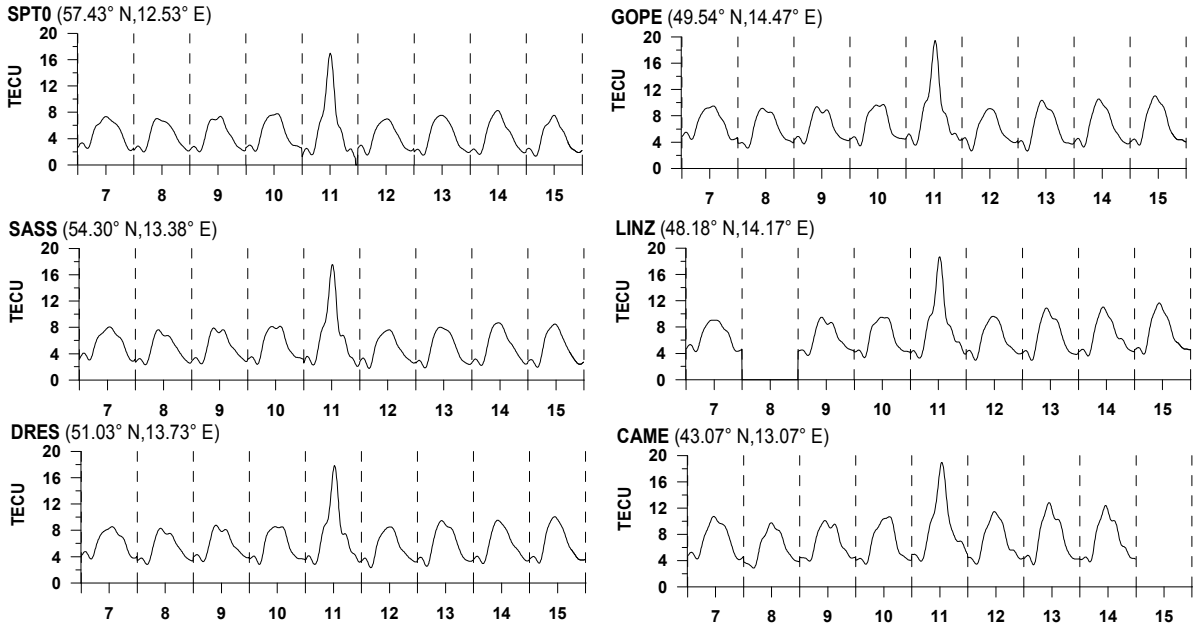

Fig.3. Diurnal variations of TEC over Europe at different latitudes during October 7 – 15, 2008

This enhancement was clearly observed in the foF2 variations over European ionosondes Juliusruh, Pruhonice and Rome. The foF2 increased from 5.6 to 9.0 MHz during the 3 h period at Juliusruh and from 5.6 to 8.3 MHz during the 3 h period at Rome. Comparison of ionosonde-derived electron density profiles for quiet and disturbed days indicates essential enhancement of electron density over European region around 13 UT. Peak electron density increased by a factor of 2.9, height of F2 layer maximum was risen by 60 km in comparison with the quiet day profile characteristics.

Figure 4 illustrates the changes of FORMOSAT-3/COSMIC radio occultation profiles registered at 13 UT over European region for a quiet and disturbed day. There is observed the increase of the F2 layer height and significant (by a factor of 3) increase in the F2 peak density.

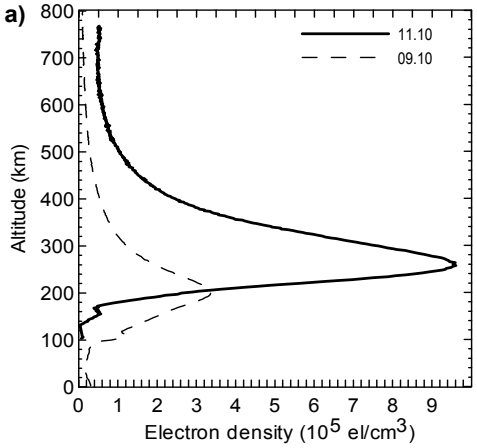

Fig. 4. Comparison of COSMIC electron density profiles at 13 UT on October 9 and 11, 2008.

In order to analyze the changes of the ionospheric electron density distribution the global electron density maps for different altitude slices were calculated on the base of globally distributed FORMOSAT-3/COSMIC radio occultation profiles. A considerable enhancement of the spatial scale and magnitude of the equatorial ionization anomaly is observed within the African longitudinal sector at all slices at 12 UT. The graphs illustrate the uplifting of F2 layer near noon on October 11. The most pronounced effect of the electron density increase occurred at the altitude

range of 300-350 km. It is also necessary to note that the considerable Ne increase effect at the altitudes of 350-400 km illustrated the modification of the topside part of the ionosphere.

Results of analysis of TEC and electron density variations during ionospheric storm at other longitudinal sectors and various altitudinal regions will be discussed in details during presentation.

3. Acknowledgments

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