GPS-based Monitoring of the European and Polar Ionosphere

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1. Introduction

It is well recognized that the space weather induces severe ionosphere perturbations capable of causing various technical problems and can also adversely influence the GNSS reference services (Jakowski et al., 2001; 2002). For example, the highly dynamical and strong deviations of the ionosphere electron density structure during storms may cause unpredictable range errors by rapid phase and amplitude fluctuations of the satellite signals. GNSS reference services at middle latitudes can also be affected by strong ionospheric perturbations propagating from the polar regions. Being a robust integral characteristic of the ionosphere, the TEC is quite helpful when monitoring and analysing ionospheric storm phenomena (Jakowski, 1996; Jakowski et al., 1999; Stankov, 2002). Presented here is the DLR experience in monitoring the recent, November 2004, ionospheric storms and their impact on the TEC behaviour.

2. Monitoring over the European region

Since 1995 DLR has been operating a system for regularly processing ground based GPS data and producing maps of the integrated ionospheric electron content (TEC) over the European region (http://www.kn.nz.dlr.de/daily/tec-eu). The high time resolution, 30s data, obtained mainly from the ground receiving stations of the International GPS Service (IGS) allow the determination of slant TEC values along numerous satellite-receiver links over the European area. The calibrated slant TEC data are then mapped to the vertical by applying a mapping function which is based on a single layer approximation at hsp=400 km. Finally, the observed TEC data are assimilated into a regional model, NTCM (Neustrelitz TEC Model), ensuring that the final map provides real values at/near the points of measurements and model values over the areas without measurements (Jakowski, 1996).

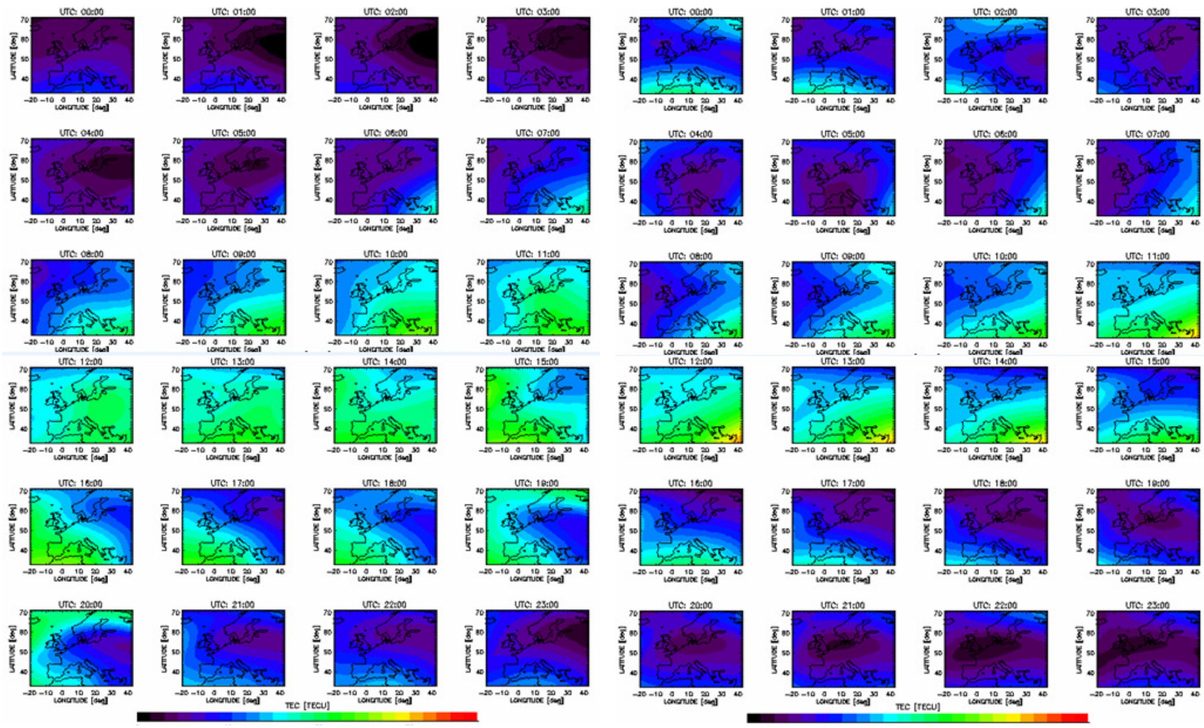

Fig.1. European TEC maps for 7/11/2004 (left panel) and 8/11/2004 (right panel).

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3. Monitoring over the North Polar region

Enhanced space weather impact is expected first on the high-latitude ionosphere because of its stronger electro-dynamic coupling with the magnetosphere and the solar wind. The high latitude electric field, precipitation of energetic particles, and plasma convection, are probably the most powerful driving forces for the highly dynamic and complex processes. During storms, the strong enhancements of the solar wind energy generate large perturbations in the high-latitude ionosphere and thermosphere resulting in significant variability of the plasma density, which commonly propagate towards lower latitudes. Obviously, the high-latitude region is like a "space weather kitchen" for several perturbation phenomena observed at lower latitudes. Therefore, the regular monitoring of the total ionization in this region can significantly improve our understanding of the complex coupling processes between the solar wind, magnetosphere, ionosphere and thermosphere. In order to do this we monitor the Northern high latitude ionosphere, applying a similar procedure as for the European ionosphere (Jakowski et al., 2002). Vertical TEC values are computed for a grid consisting of 768 grid points within the latitude range between 50°N and 90°N enabling the imaging of large scale perturbations in the auroral zone (http://www.kn.nz.dlr.de/daily/tec-np).

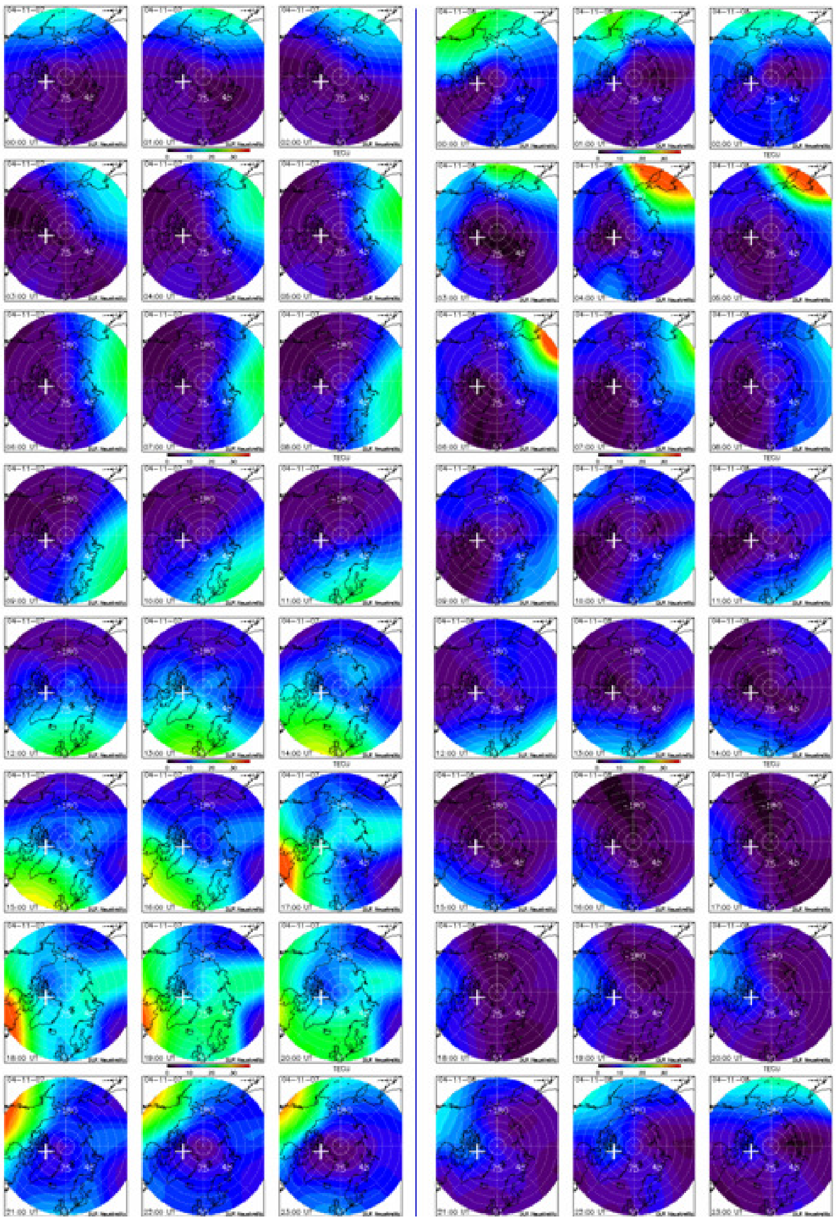

Fig.2. North Polar TEC maps for 7/11/2004 (left panel) and 8/11/2004 (right panel).

4. Discussion

The monitoring results presented here cover the first 48 hours, probably the most attractive period, of the storm which started on 7 November 2004.

Indications of an upcoming storm are clearly seen on the North Polar and European maps from 1200UT. In addition to the strong overall increase in TEC, a patch of increased ionisation is detected over the North Pole. During the next few hours, the patch grows in size and clearly moves southward over the night-time hemisphere. The day-time hemisphere was affected too. As the European maps show, an area of higher ionisation appeared in the North East (as early as 0900UT) which propagated toward lower latitudes and notably increased the TEC over the entire continent. The described process, although with variable intensity, was maintained during most of the day and the evening hours of 7 November.

During the night and morning hours of 8 November 2004, the storm was in full swing and the ionosphere was severely perturbed, as both types of maps clearly show. Over Europe, larger than usual TEC values were maintained overnight, mostly due to the influx from the day-time ionosphere; the fact is supported by the polar maps showing extremely high TEC over Asia in the 0400-0600UT time frame. Oppositely, the polar map at 0800UT and those afterwards show lower than normal TEC, indicating a depleted ionosphere and the beginning of the storm recovery phase. Nevertheless, at the lower latitudes of Europe, ionosphere disturbances were observed throughout the day.

5. Summary and Conclusion

GNSS-based TEC mapping, thanks to its high spatial and temporal resolution, is a reliable tool for monitoring the space weather impact on the Earth's ionosphere, which can also improve our insight into the dynamics of ionospheric perturbation processes and can be used eventually for predicting their impact/effects. DLR has initiated a project (SWIPPA) offering an operational service for monitoring and evaluating the impact of space weather on precise positioning (Jakowski et al., 2004). In this service, the TEC monitoring plays a crucial role and the first results are quite promising.

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