Impact of auroral disturbance on GNSS positioning

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The electron density irregularities in the high latitude ionosphere may alter phase and amplitude fluctuations of GPS signals [1, 2]. The low frequency GPS phase fluctuations may be caused directly due to electron density changes along the radio ray path, or the total electron content (TEC) changes. Strong TEC fluctuations can complicate phase ambiguity resolution due to an increased number of undetected and uncorrected cycle slips [2]. The loss of signal lock in GPS navigation was associated with aurora [3]. The experimental evidence of positioning errors connected with spatial and temporal variations in the intensity of auroral arcs was demonstrated by Chernouss [4].

In this report, GPS measurements of the Euref Permanent Network were used to study an influence of auroral disturbance on positioning errors during the 22-23 June 2015 geomagnetic storm.

Dual-frequency GPS measurements for individual satellite passes were served as raw data. As a measure of fluctuation activity, the rate of TEC (ROT, in the unit of TECU/min, 1 TECU=10^{16} electron/m^2) at 1 min interval was used, as a measure of TEC fluctuations intensity — index ROTI.

Fig.1 demonstrated development of the storm by time series of the Dst and AE indices.

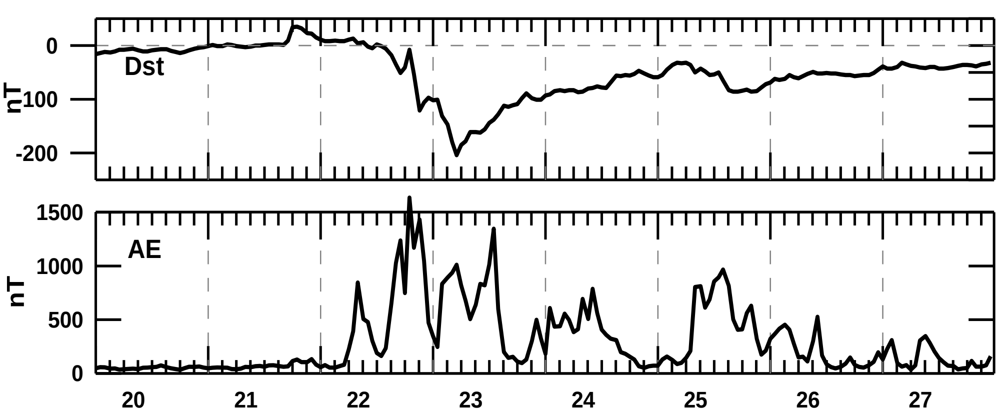

Figure 1.

The accuracy of GPS positioning is strongly depended on ionospheric fluctuations (scintillations) that increase during geomagnetic disturbances. The intensive fluctuations lead to phase cycle slips and signal loss of lock, which are more stronger on the L2 signal. Losses of signal can cause problems when applying the ionosphere free combination (ion-free) that is generally used in Precise Point Positioning (PPP). Kinematic positioning is in general degraded when a small number of GPS satellites is available, which frequently occurs under fluctuation activity GPS signals. As it shown by Marques et al. [5], under the intensive fluctuations a number of cycle slips and loss lock signals can sharply increase causing jumps in the positioning errors which reached about 8 m for a height component.

We analyzed the link between intensity of TEC fluctuations (index ROTI) and Precise Point Positioning (PPP) errors using the GIPSY software of NASA Jet Propulsion Laboratory (http://apps.gdgps.net). Precise Point Positioning is a single receiver processing strategy for GNSS observations that enables the efficient computation of high-quality coordinates, utilizing indifference dual-frequency code and phase observations (RINEX files) by using precise satellite orbit and clock data products. We analyzed how TEC fluctuations influence on positioning errors for stations located at different latitudes along 20°E longitude during the active phase of the storm (22 June).

The 3D position errors were computed with a 5-min interval. The high correlation between positioning errors and ROTI was found by Jacobsen and Dähnn [6.] as well as by Jacobsen and Andalsvik for 17 March 2015 geomagnetic storm at the European sector [7]. Positioning errors increase exponentially with ROTI increasing [6]. We analyzed a link between ROTI and the 3D position errors for stations located in the latitudinal range of 69-54°N. In calculating of the ROTI index, only satellites observations with elevations above 20° have been included. In calculating of the 3D position errors, we used also the same procedure.

Figure 2 shows temporal variations ROTI and the 3D positioning errors at stations spaced by a latitude during the storm. On the plot, variability of ROTI values calculated for all visible GPS satellite passes over selected stations for every epoch shown by dots. We can note a very good similarity in the ROTI and positioning errors behavior, an increase of ROTI values followed by an increase of positioning error at all considered stations. The positioning errors reached 15 m at auroral latitudes where fluctuations intensity was maximal. At lower latitudes, the errors decreased as well as intensity of fluctuations. At subauroral latitudes, the errors decreased to the background conditions, although the fluctuations remained noticeable.

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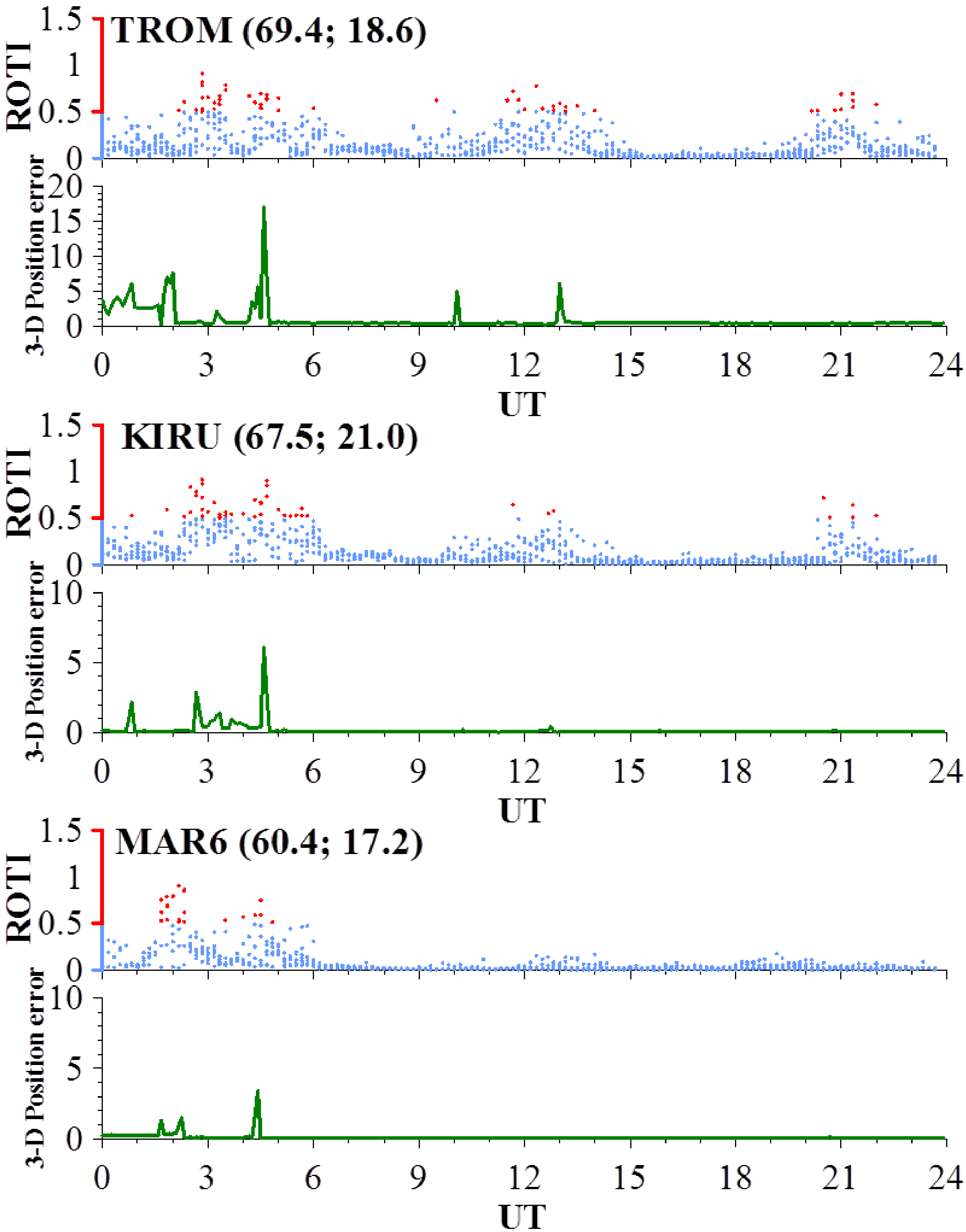

Figure 2. Time variations of TEC fluctuations (index ROTI) and 3D positioning errors during the storm day of 22 June 2015 at different latitudes.