Impact of severe geomagnetic disturbances on GPS precise positioning

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Abstract

We used the high latitude GPS observations of the IGS (International GNSS Service) network to study the GPS TEC fluctuations during the 17 March 2015 storm. The ionospheric activity was evaluated by parameters of TEC fluctuations intensity: ROT (Rate Of TEC) and ROTI (Rate Of TEC Index). We analyzed the TEC fluctuations associated with auroral disturbances, by using the European GPS stations at latitudes from 50 to 70N. The strong TEC fluctuations are more common in the nightside auroral oval. A distinguish feature of this storm is that the main phase of the storm occurred during day time in Europe. It was unusual that during the time the TEC fluctuations were registered till 52-56N. We found the high correlation of the GPS positioning errors with ROTI. The positioning errors were computed using the GIPSY-OASIS software for the stations located at different latitudes.. The positioning errors can reach more than tens meters during auroral disturbances. It is of high importance for navigation in Arctic.

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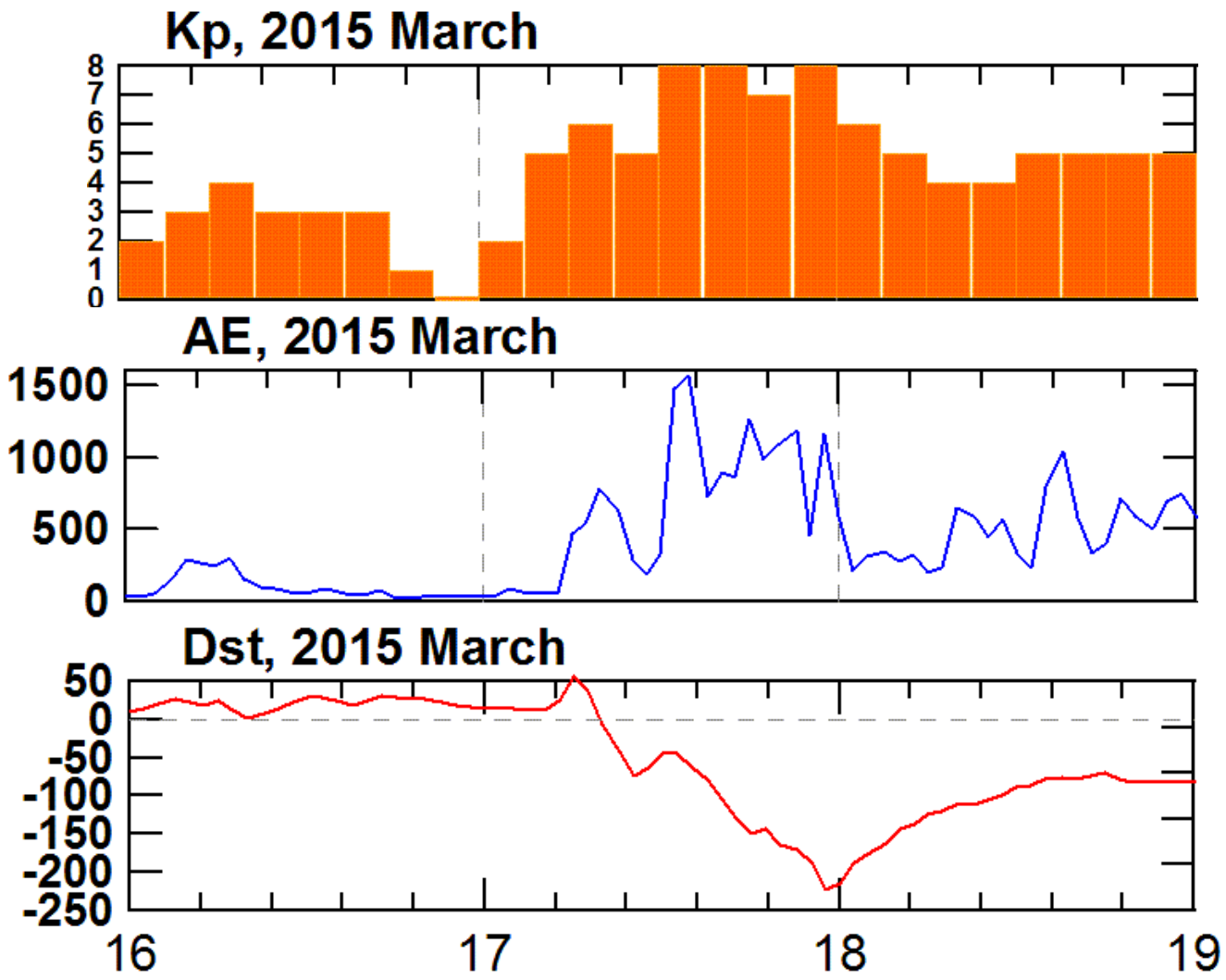
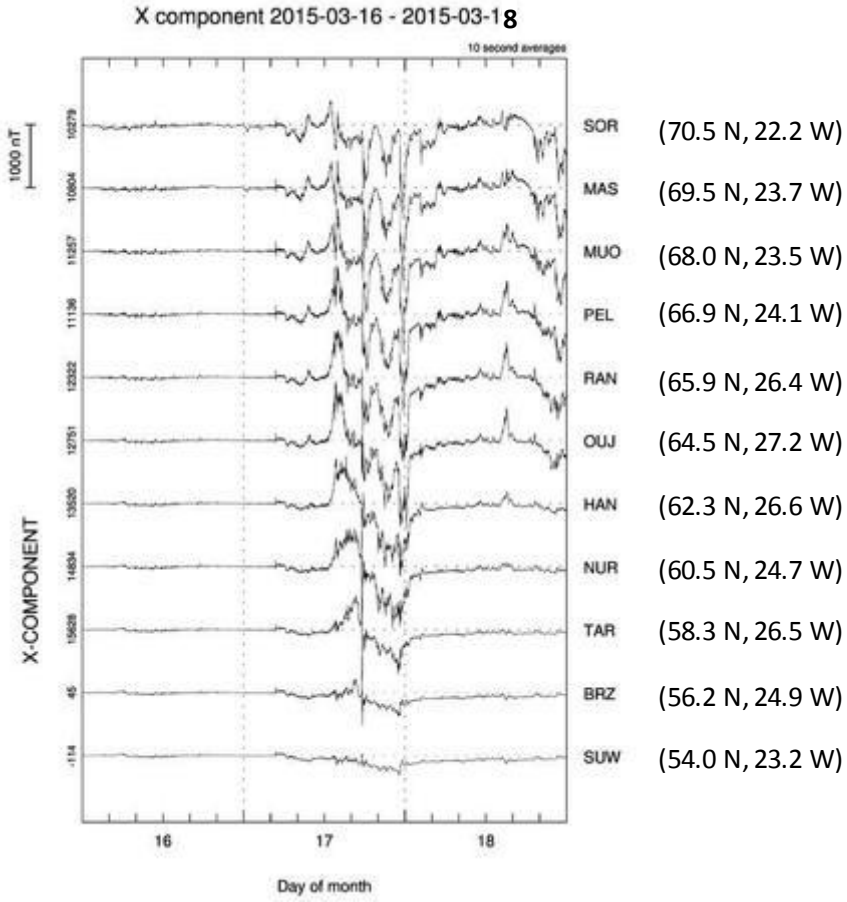
Kp, Dst and Ae variations during March 16-18, 2015.

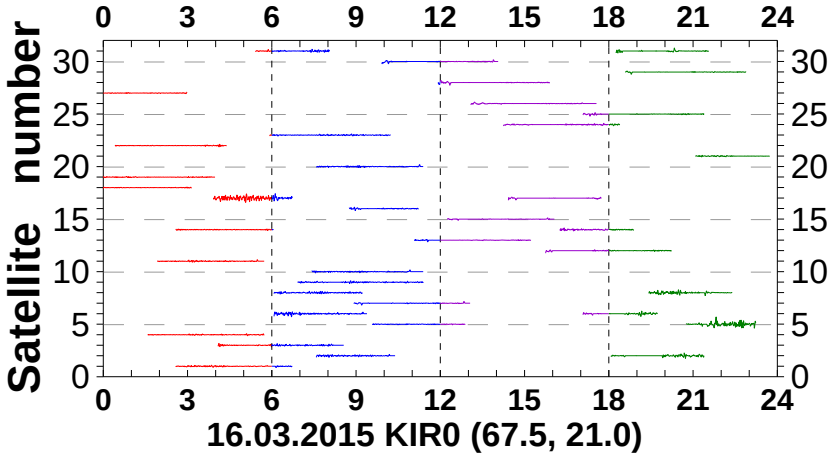


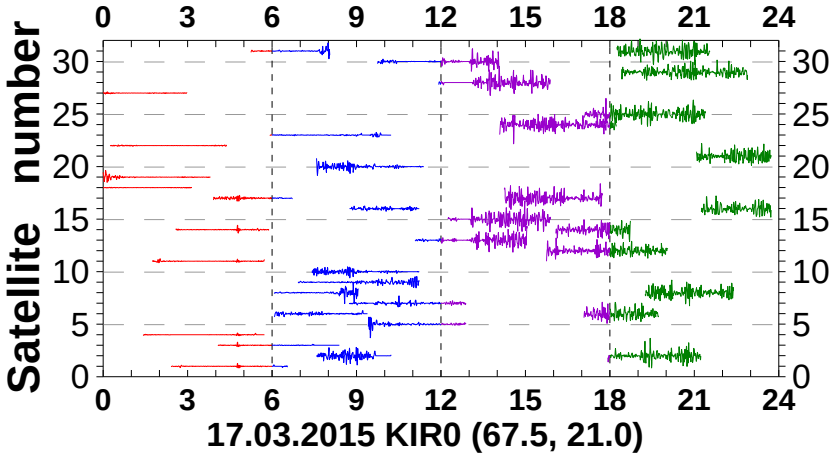


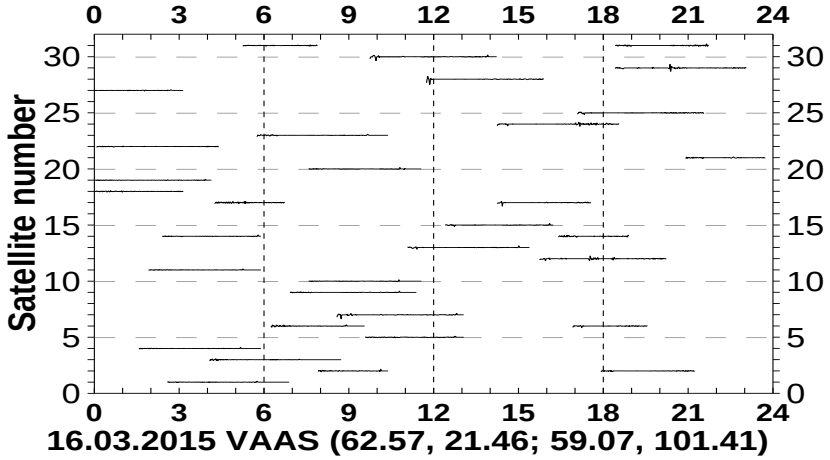
The variations of the geomagnetic field X-component at Scandinavian network.

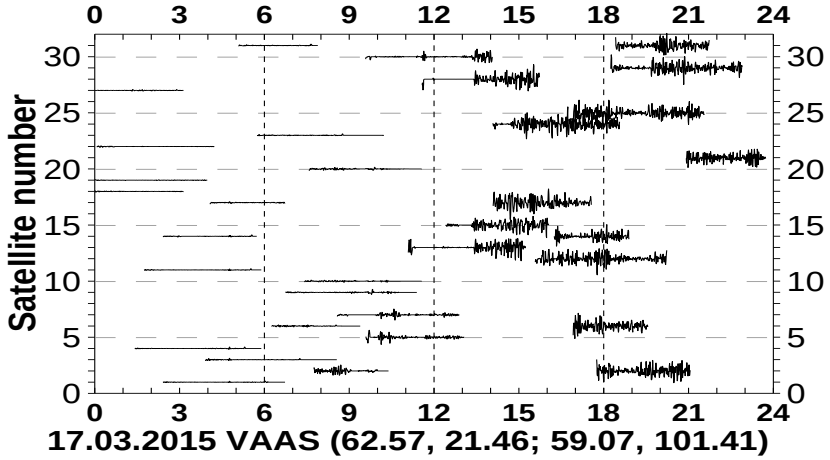
Data from IMAGE Magnitometer Array:
http://space.fmi.fi/image/

Occurrence of TEC fluctuations on all satellite passes over KIR0 and VAAS stations for quiet (March 16) and storm (March 17) day.

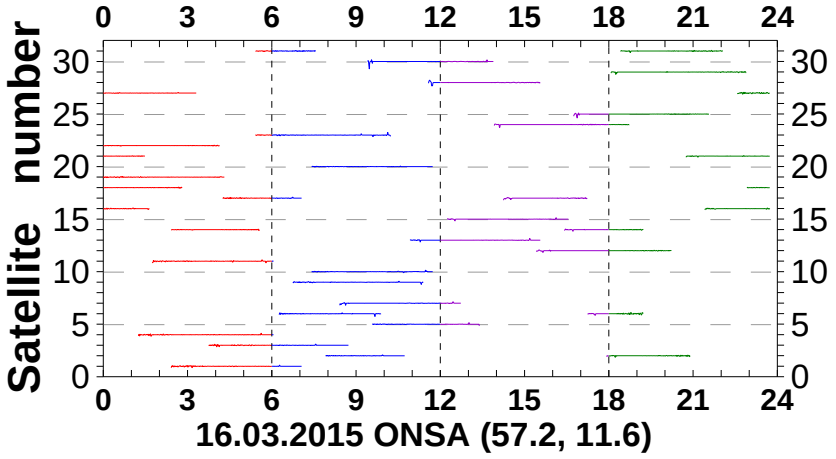


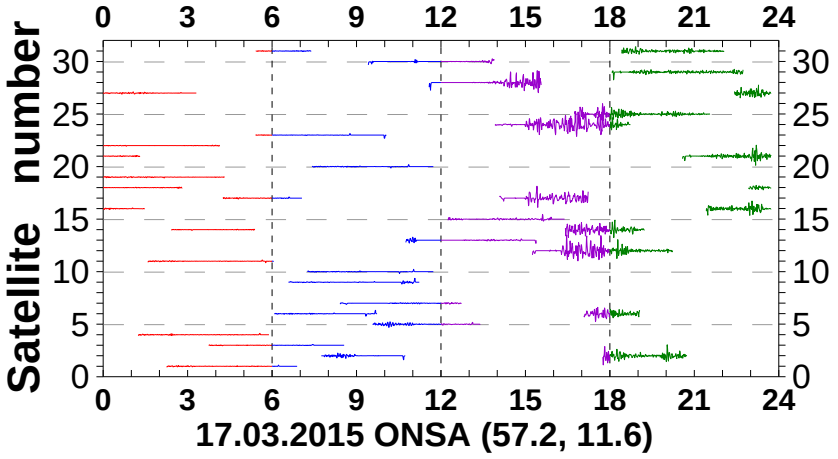


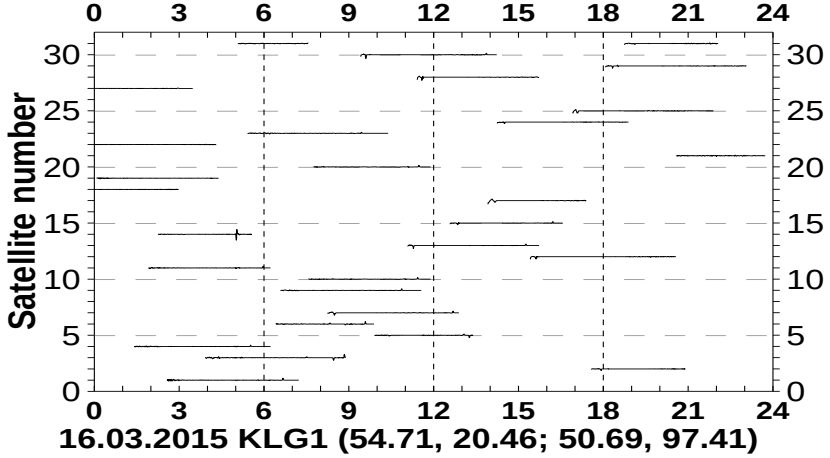


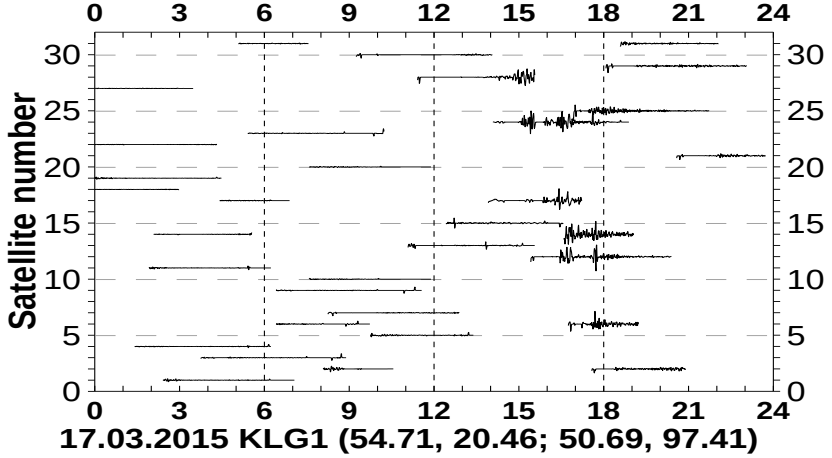


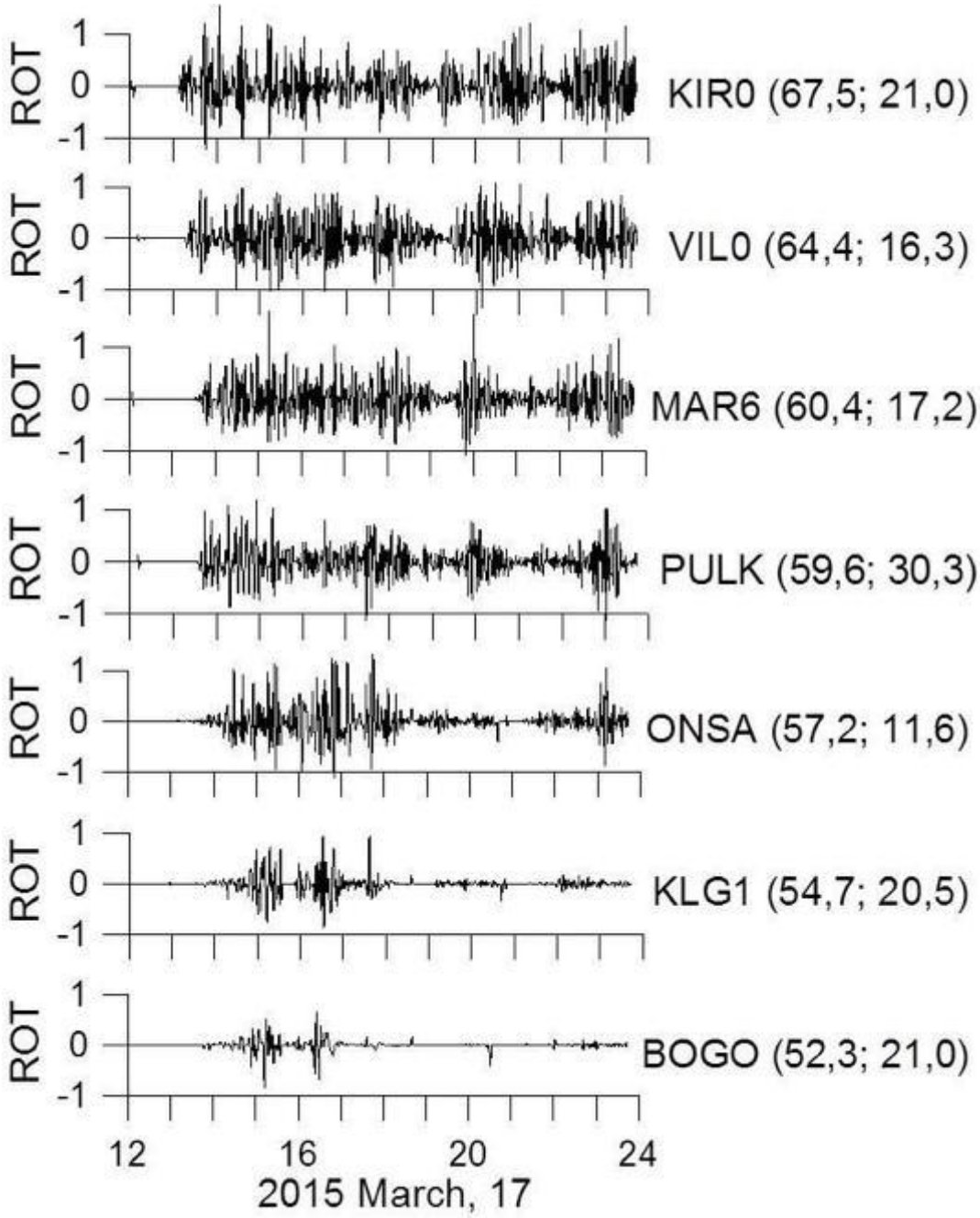
Occurrence of TEC fluctuations on all satellite passes over Onsala and Kaliningrad stations for quiet (March 16) and storm (March 17) day.



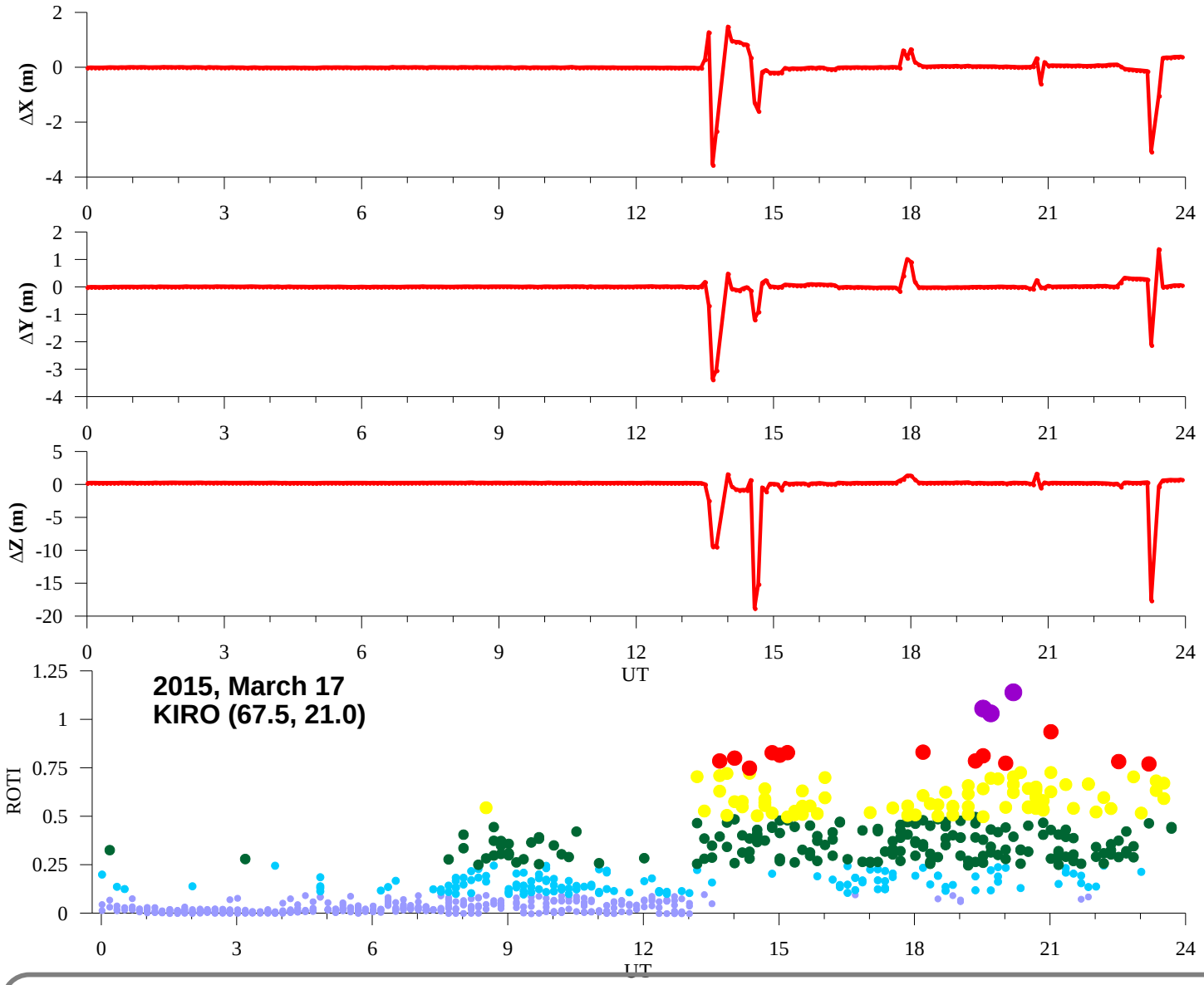




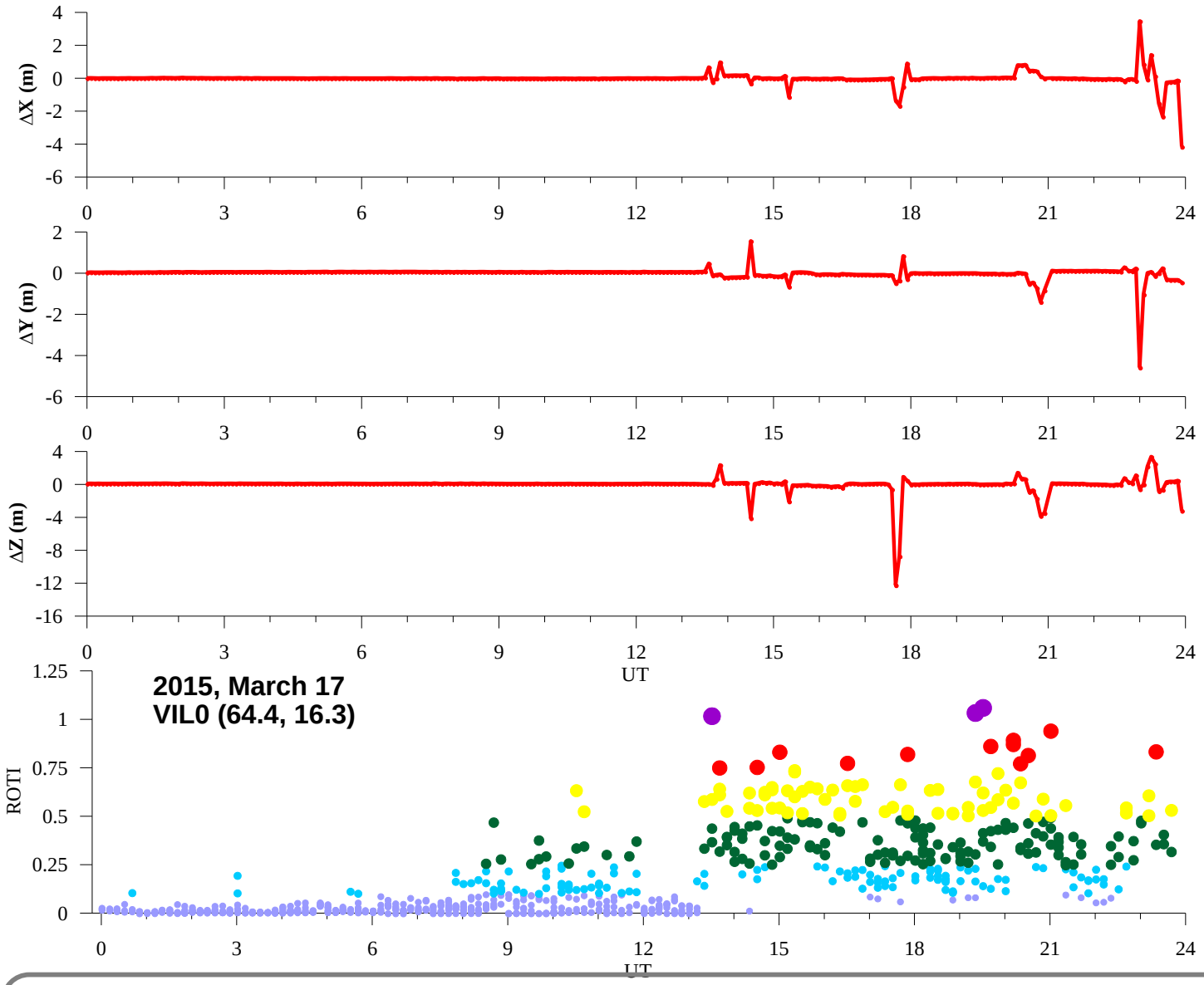




Latitudinal occurrence of TEC fluctuations for satellites PRN 21 and PRN 28.



Positioning errors $\Delta x(x_i-\bar{x})$, $\Delta y(y_i-\bar{y})$, $\Delta z(z_i-\bar{z})$ and intensity of TEC fluctuations (ROTI) during storm.



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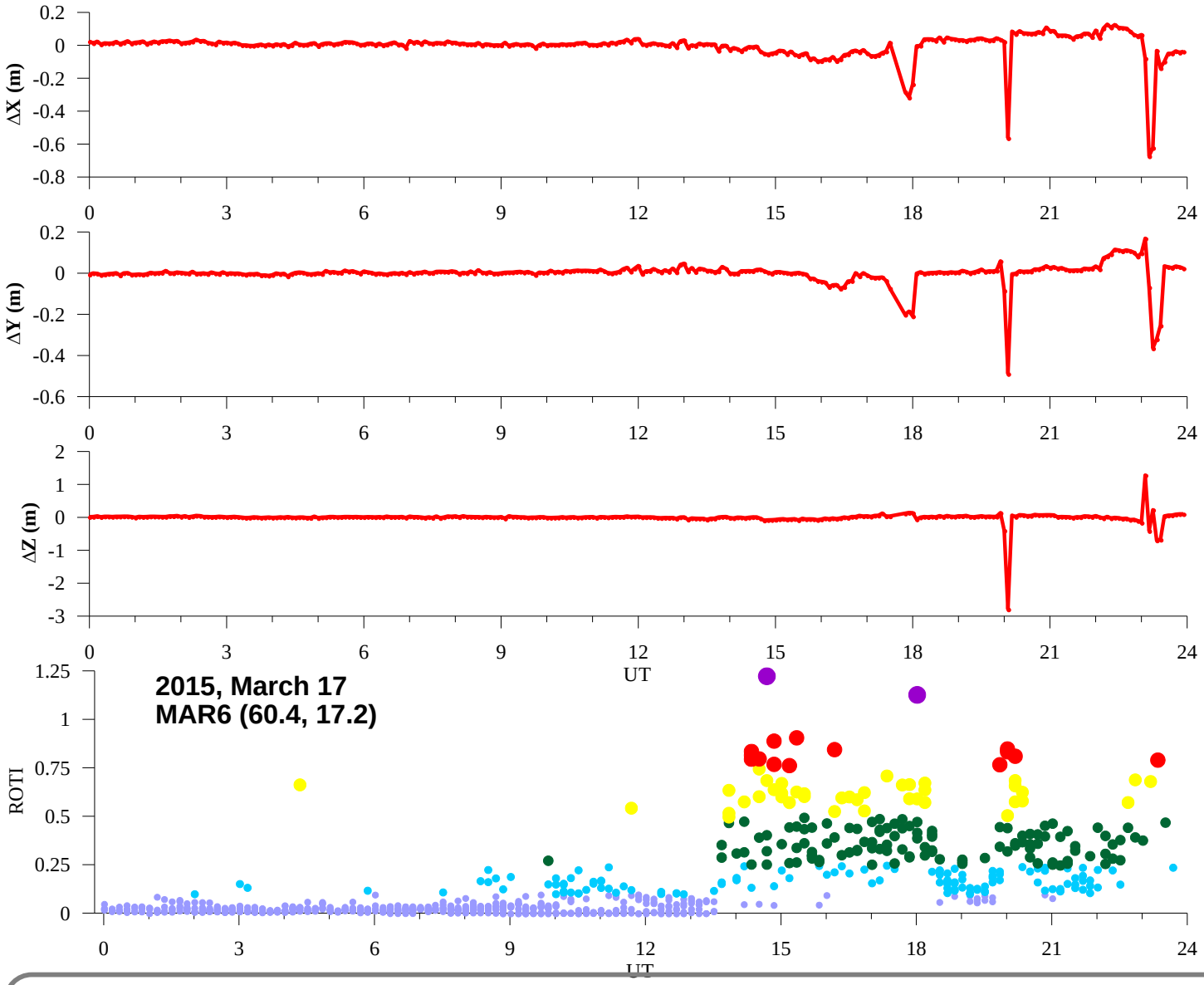

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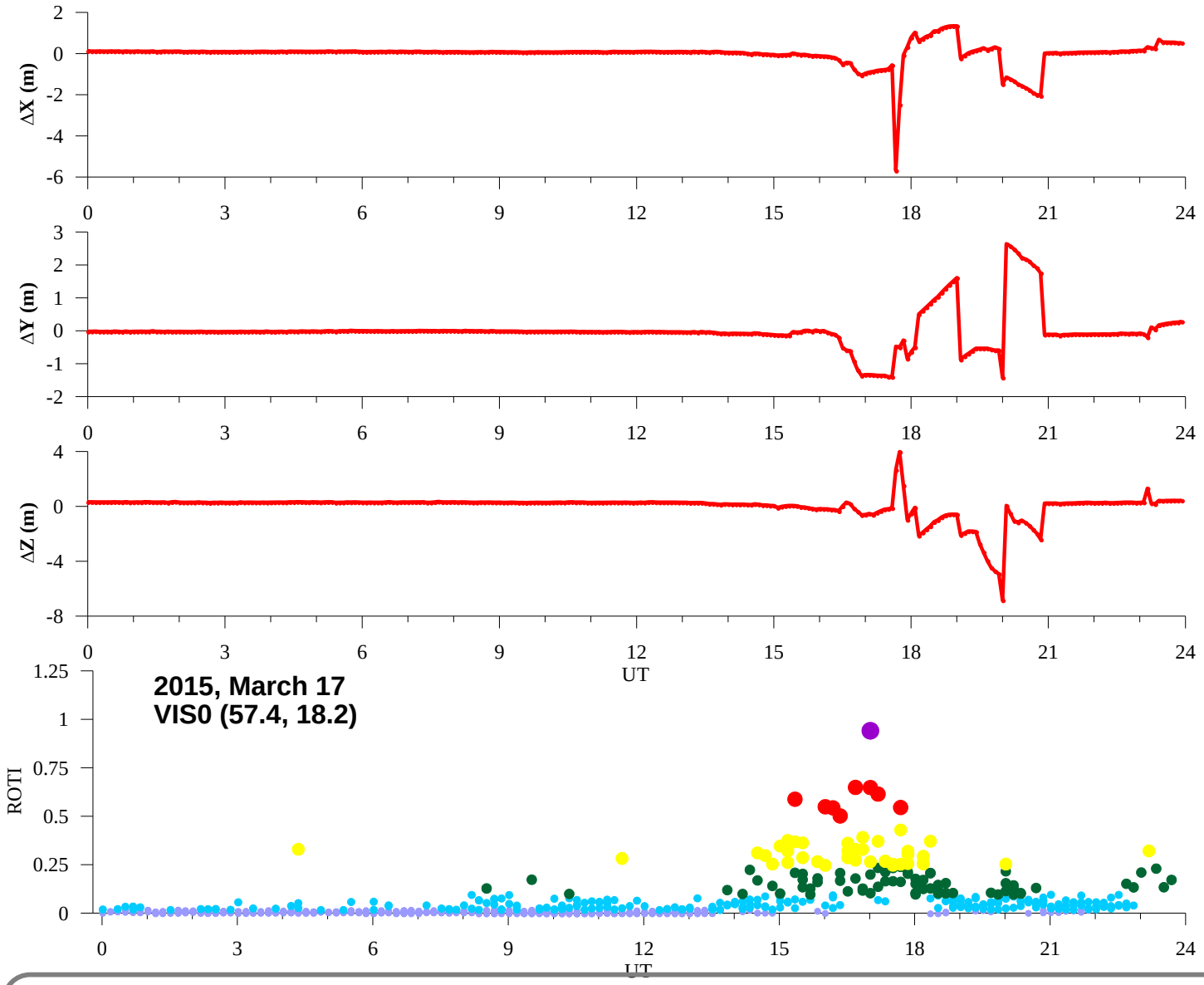

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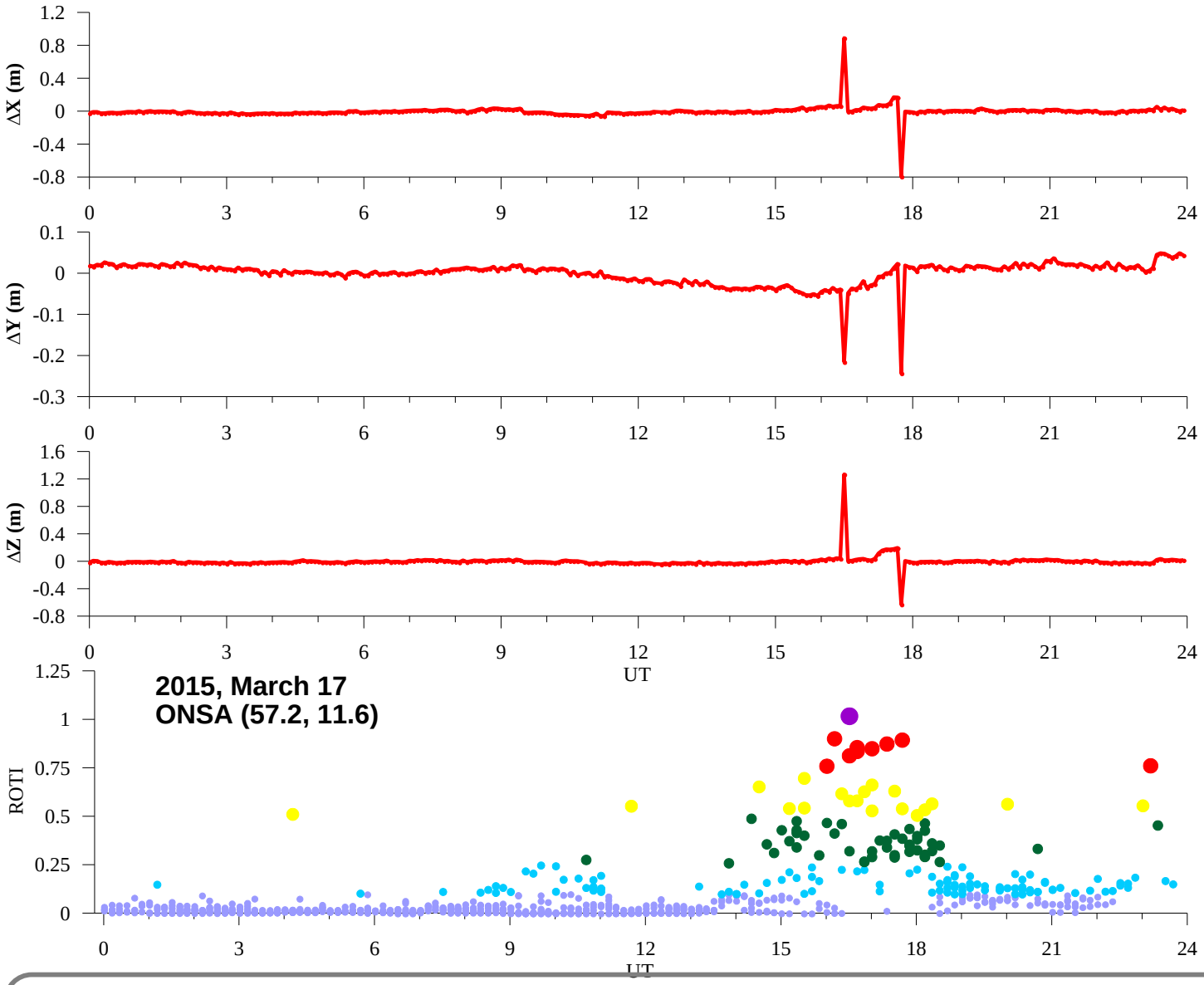

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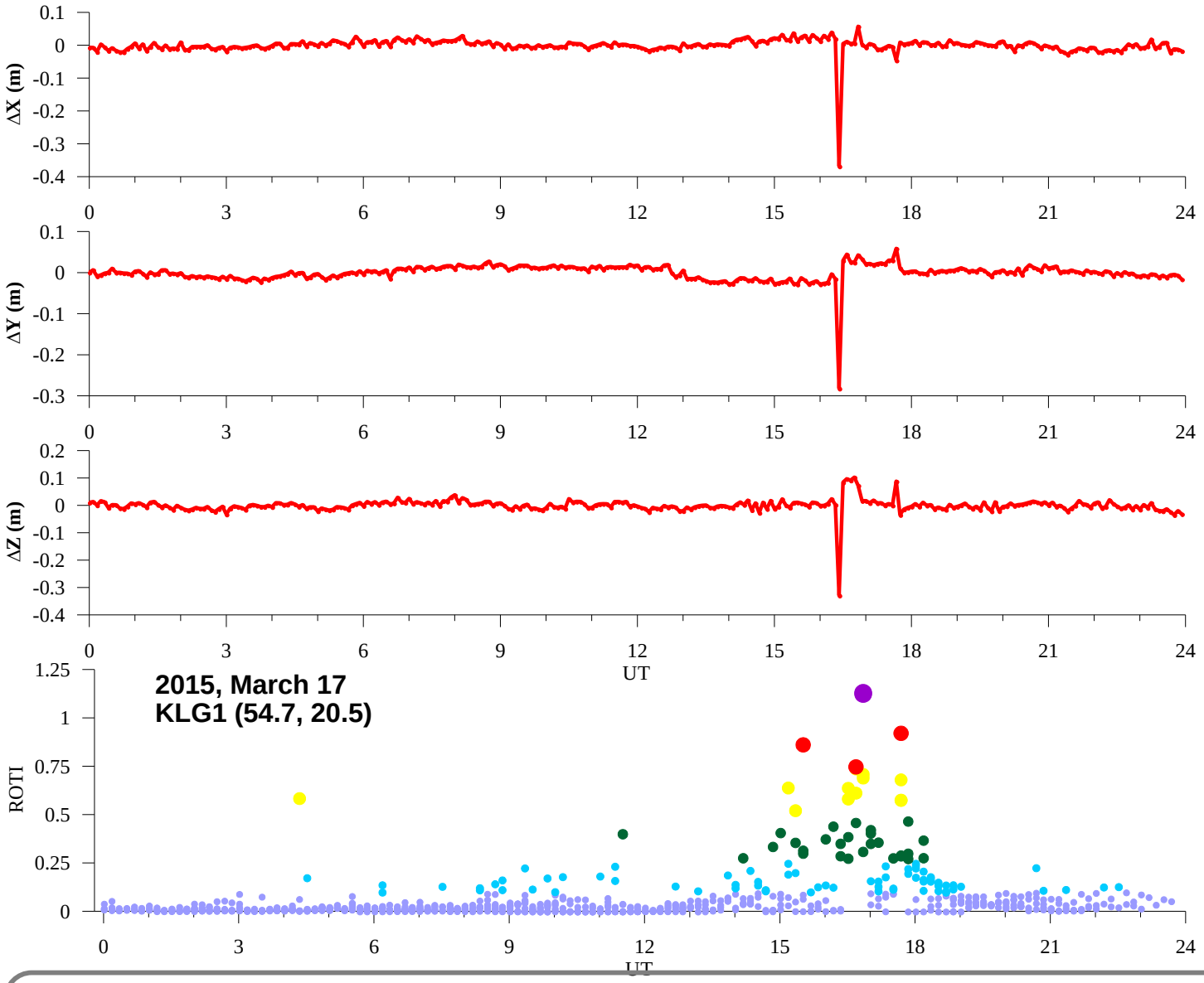

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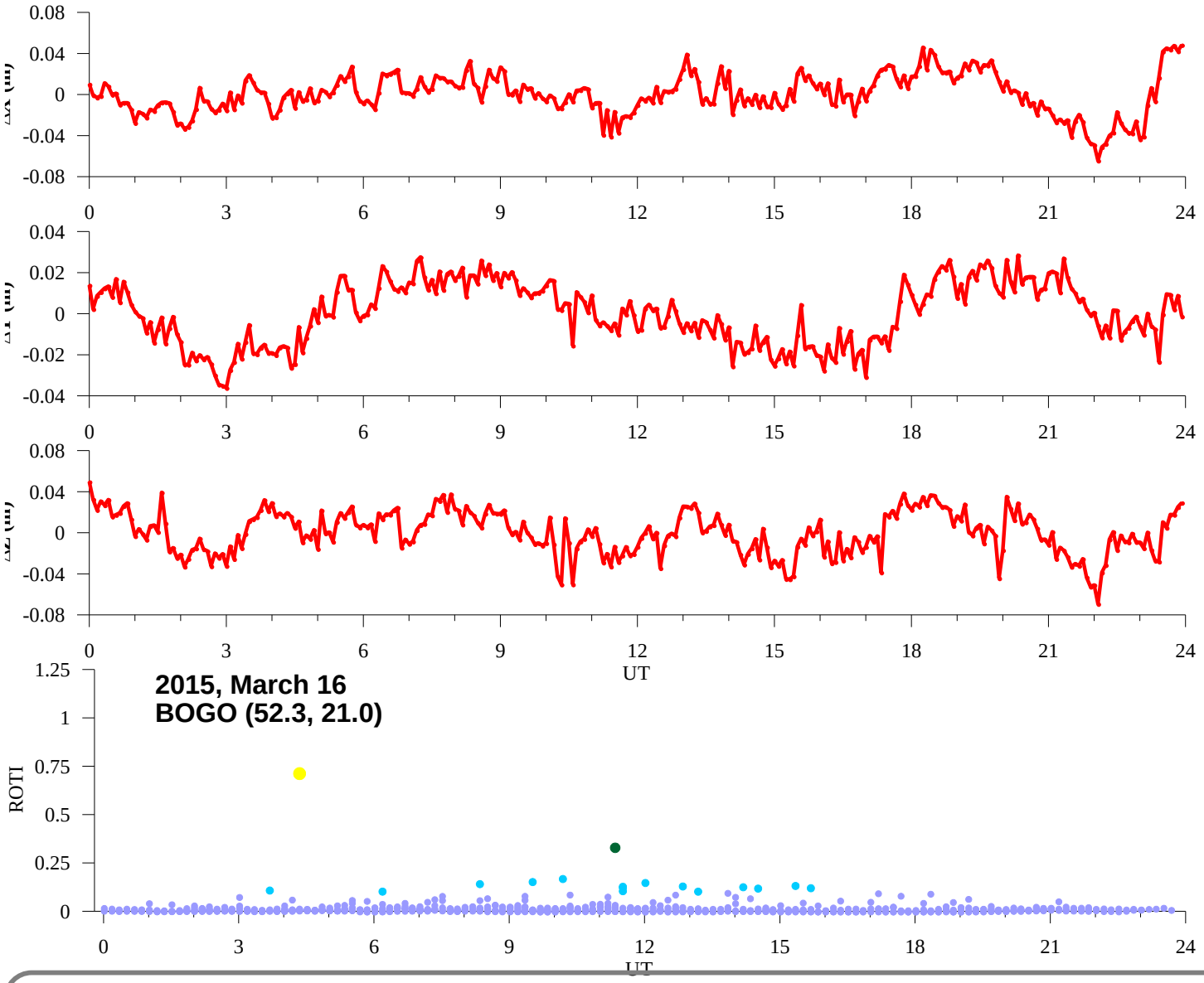

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Acknowledgements: We thank IGS and EPN for providing GPS data, the Institutes who maintain the IMAGE Magnetometer Array, Grants of RFBR

Conclusion

During the geomagnetic storm the intense TEC fluctuations were observed at the auroral, subauroral and mid-latitude ionosphere. Joint analysis of the observed phase fluctuations of GPS signals, and fluctuations of the geomagnetic field demonstrated rather good agreement during intensification of the auroral activity. During the peaks of the auroral activity the weak GPS phase fluctuations were registered even at the mid-latitude station BOGO. In combination geomagnetical measurements this fact confirms the equatorward expansion of the auroral oval. Intensity fluctuations decrease to south. The strongest fluctuations were registered in aurora zone. Distinguish feature of this storm is that the main phase of the storm occurred during day time in Europe. It was unusual that during the time the TEC fluctuations were registered at mid-lelatitudes. The mark TEC fluctuations were found over BOGO station (52.3N). We found good similarities between time development of substorm and fluctuations GPS signals. There is a correlation between Precise Point Positioning (PPP) error and ROTI. Maximal errors took place at auroral stations. PPP sharply increase when intensity TEC fluctuations exceeded some values in particular than ROTI more than 1.0 TECU/min.

Acknowledgements: We thank IGS and EPN for providing GPS data, the Institutes who maintain the IMAGE Magnetometer Array, Grants of RFBR 16-05-01077, 7-45-510341 and program № 7, PRAN.

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