IONOSPHERIC SUPERSTORMS AND THEIR EFFECTS ON GNSS

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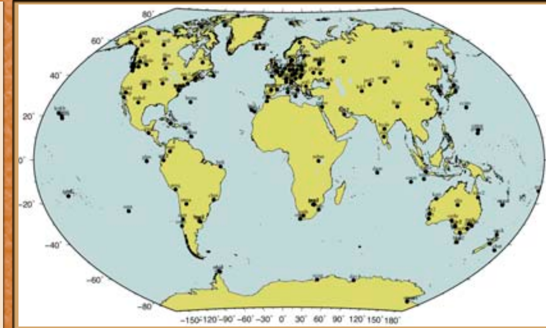
The most prominent ionospheric effects produced by intense geomagnetic storms at middle and low-latitudes, such as the dayside ionosphere uplift and large TEC increase within the crests of the equatorial ionization anomaly (EIA), were recorded during only a few geomagnetic storms during 2000-2006. Based on observations of ionosphere TEC response to more than 15 geomagnetic storms, we found that combination of intensive dawn-to-dusk electric field and southward IMF Bz seems to be the decisive factor for development of the ionosphere super-storm effects.
On the other hand, ionosphere is known to affect the radio signals propagating through it. These effects have negative influence on performance of satellite and navigation systems

The main purpose of this study is to analyze the operation quality of GPS during geomagnetically disturbed conditions.



GPS failures

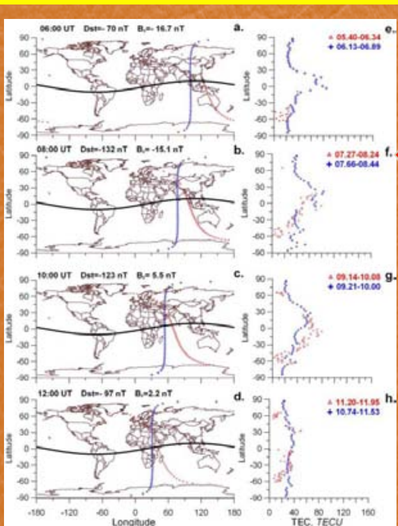
GPS phase slips - (L2 – failures) – *Poor navigation accuracy, impossibility of precise positioning in two-frequency mode*

Count omissions in RINEX files – (L1-L2 failures) – *Positioning is impossible, GPS signal is not registered at all*

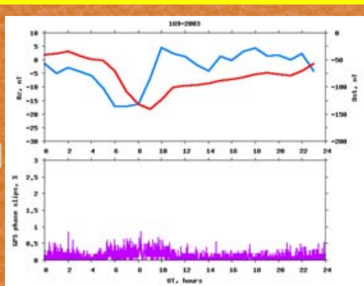
We determine values of TEC from phase difference of frequencies L1-L2 and we consider a sudden jump dTEC > 3 TECU/ 30-sec to be GPS phase slip.

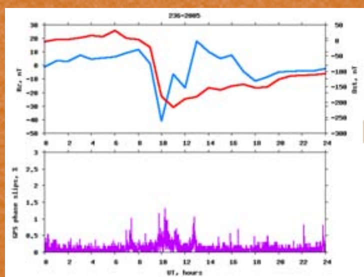
We calculate a number of GPS slips and count omissions for all satellites and all ~190 GPS receivers for every 30 seconds. We also calculate total number of observations (LOS) for each 30-sec interval. This allows us to determine the relative number of GPS slips and count omissions

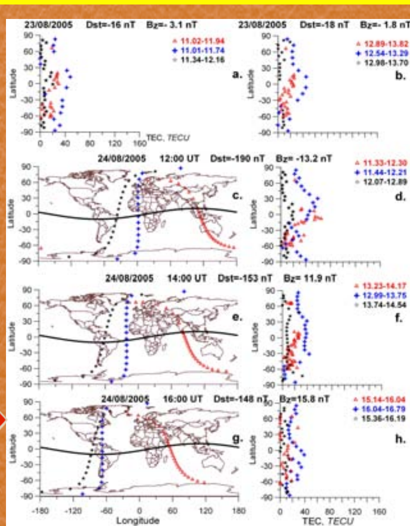
1. GPS Phase Slips During Ionosphere Storms



TEC changes during a quiet day 17 June 2003 (a,b) and the geomagnetic storm on 18 June 2003 (c-h). The satellites pass near the following sectors: Jason-1 ~14:20 LT, CHAMP ~13 LT, SAC-C data were not available

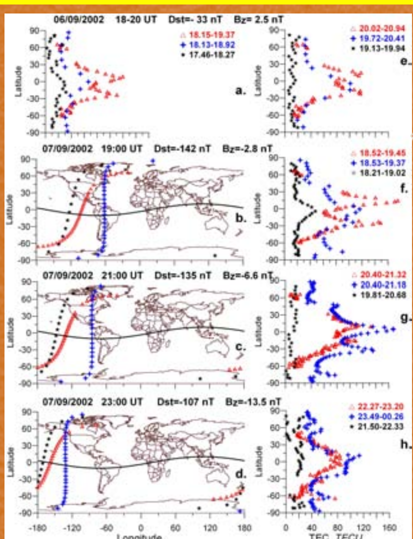




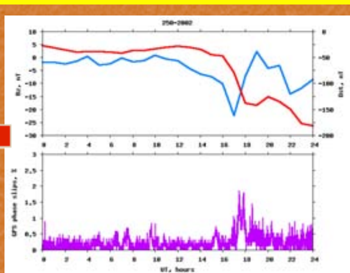


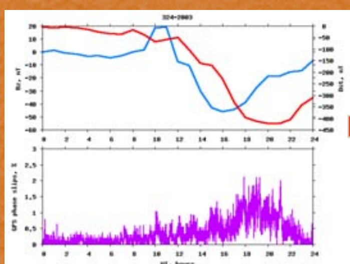
TEC changes during a quiet day 23 August 2005 (a,b) and the geomagnetic storm on 24 August 2005 (c-h). The satellites pass near the following sectors: Jason-1 ~19:30 LT, CHAMP ~12 LT, SAC-C ~10:30 LT.

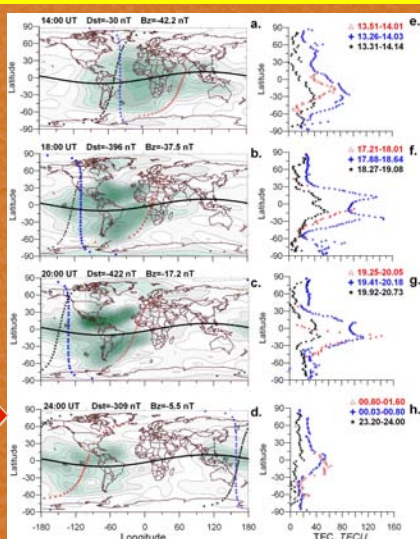
2. GPS Phase Slips During Ionosphere Superstorms



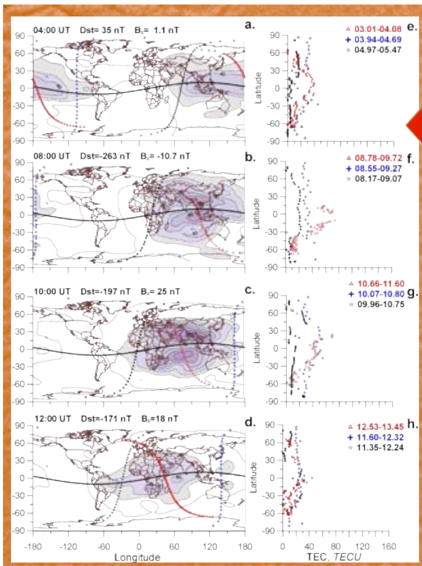
TEC changes during a quiet day 6 September 2002 (a,b) and the geomagnetic storm on 7 September 2002 (c-h). The satellites pass near the following sectors: Jason-1 ~13 LT, CHAMP ~15 LT, SAC-C ~10:30 LT.



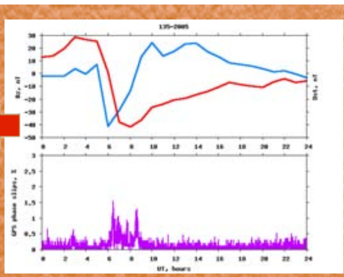




TEC changes during a quiet day 19 November 2003 (a,b) and the geomagnetic storm on 20 November 2003 (c-h). The satellites pass near the following sectors: TOPEX ~19 LT, CHAMP ~11 LT, SAC-C ~10:30 LT.

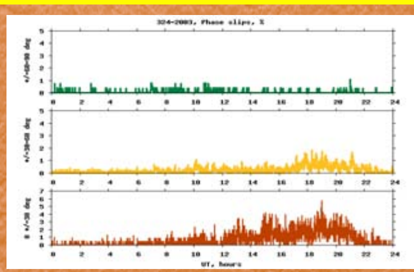


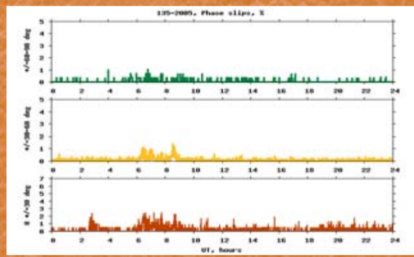
TEC changes during geomagnetic storm on 15 May 2005. The satellites pass near the following sectors: Jason-1 ~16 LT, CHAMP ~21 LT, SAC-C ~9:30 LT.



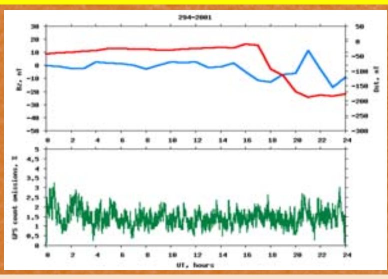
During the storm of 15 May 2005, despite drastic variations in the IMF Bz and Dst, we do not observe significant dayside increase in TEC as in the case of other ionosphere superstorms. This might be related to the geometry of the used satellites passing in the late evening (CHAMP) or early morning (SAC-C) sectors. However, during this storm, the relative number of GPS phase slips reaches 1.5%, ~3 times exceeding the background level.

3. GPS phase slips, Latitudinal distribution

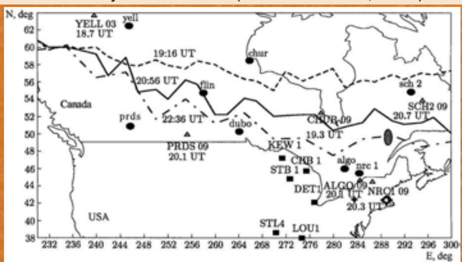


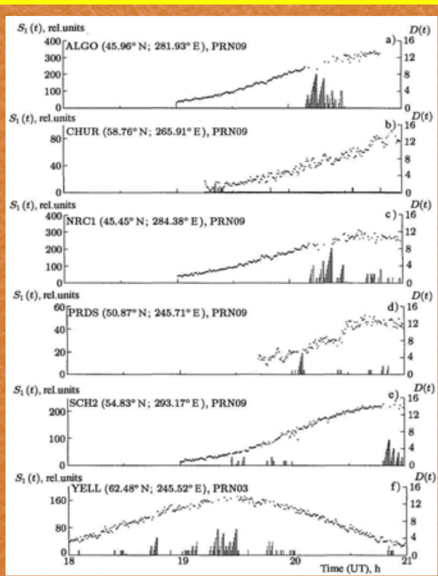


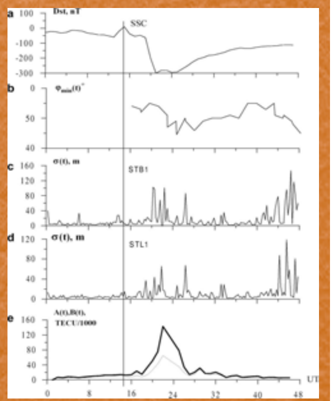
4. GPS Counts Omissions During Geomagnetic Storms



During geomagnetic storms, GPS counts omissions appear not as often as GPS phase slips. We observe omissions, for instance, on the boundary of auroral oval (Afraimovich et a., 2009).

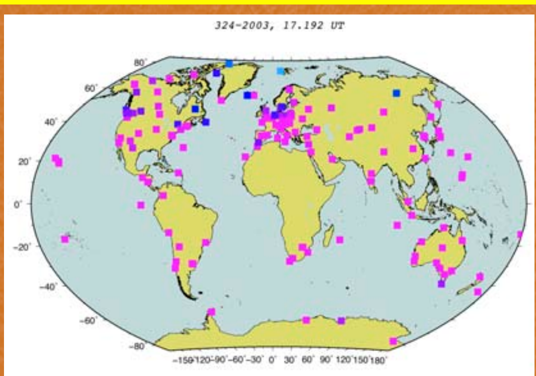


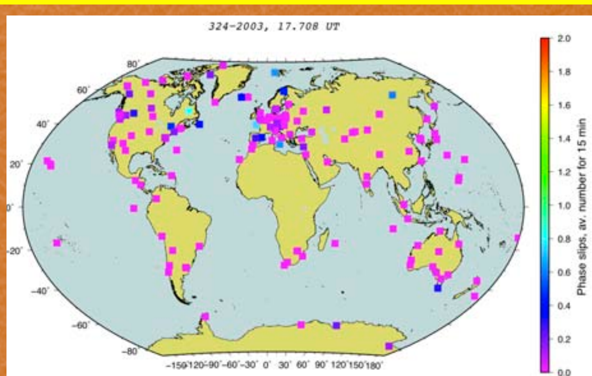




Appearance of GPS failures leads to increase of error in positioning up to 120-150 m compared to the quiet-time value of 20 cm (Afraimovich et al., 2009).

5. Global maps of GPS slips





6. CONCLUSIONS

During geomagnetic storms, the number of GPS phase slips increases to 1.5-3%, 3-4 times exceeding the background. The number of slips is larger for those events that can be classified as ionosphere superstorms. The largest contribution in total number of phase slips is done by low- and by mid-latitudes.

Counts omission occur on the boundary of auroral oval, which expands towards mid-latitudes during geomagnetic storms, worsening positioning accuracy of GPS.

Acknowledgements

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7. References

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