GPS performance during ionospheric storms and solar radio-bursts

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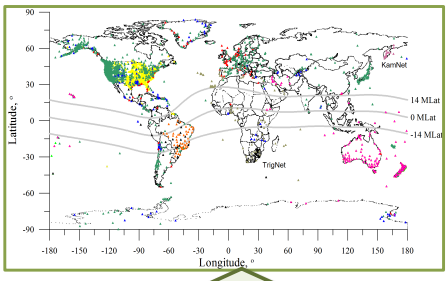
It is known that the performance of global navigation satellite systems (GNSS) can be significantly perturbed during space weather events. Propagation of GNSS signals depends directly on the state of the ionosphere, since intensive irregularities and/or gradients of electron density modify the parameters of propagating waves. Ionospheric perturbations during geomagnetic storms are known to be the major source of such intensive ionospheric irregularities, indicating on large impact on GPS/GNSS performance. A part from the ionospheric storms, intense solar radio-bursts can significantly disrupt the operation of GNSS communication, as such solar events are the source powerful radio noise.

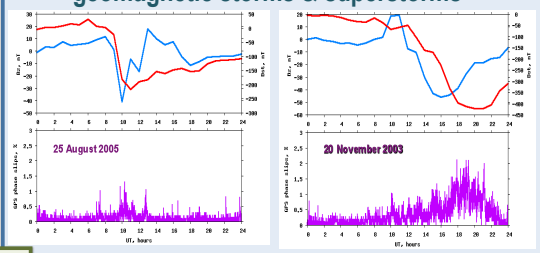
We analyze global distribution of GPS cycle slips and of GPS positioning errors during ionospheric storms and solar radio-bursts of different intensity. For our analysis we used data of GPS receivers from global networks IGS and UNAVCO, as well as numerous regional networks.



The performance of GPS was estimated from several parameters: 1) ratio of GPS cycle slips; 2) ratio of count omissions in GPS output files; 3) GPS positioning errors. GPS cycle slips and count omissions were calculated from RINEX files for all satellites and for each GPS frequencies L1 and L2. The positioning errors were calculated as standard deviation between the known precise coordinates of a ground-based GPS receiver and coordinates computed by a receiver at each moment of time.

Here we show our analysis for one of the strongest storms ever recorded – super-storm of 20 November 2003, intense storm of 24 August 2005. We also calculated ratio of GPS slips during recent major radio-bursts of 6 December 2006 and 13 December 2006.

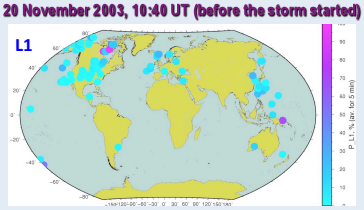
GPS slips during geomagnetic storms & superstorms



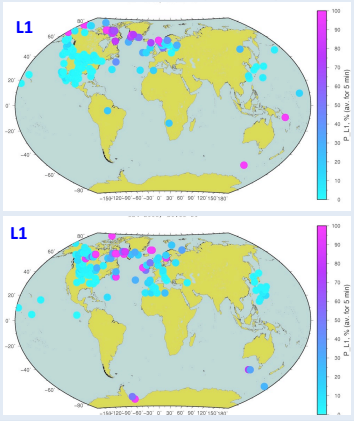
Total number of GPS slips depends on a magnitude of geomagnetic storm: stronger storms affect stronger the GNSS receivers.

Global maps of GPS phase slips

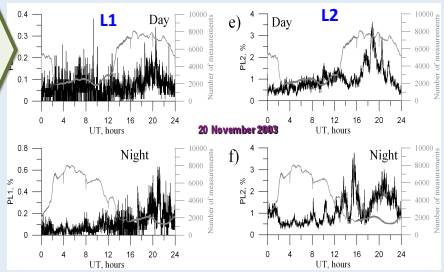
20 November 2003, 10:40 UT (before the storm started)



20 November 2003, 19:15-21 UT (max ionospheric effects)

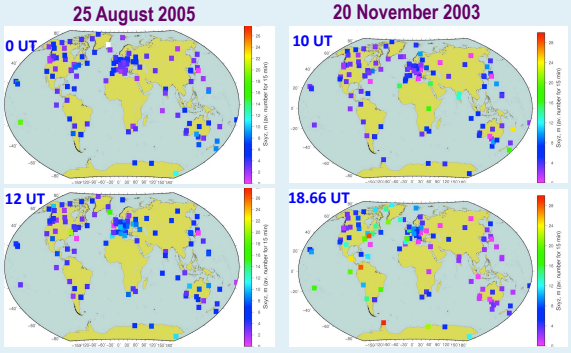


Day & Night contribution



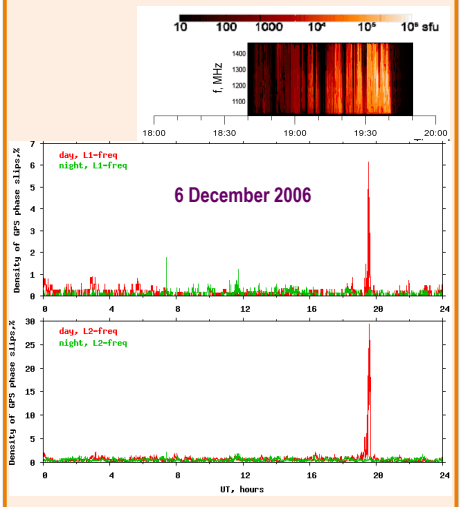
At the auxiliary frequency L2 we observe much more GPS phase slips than on the primary frequency L1. The slips occur mostly on the dayside, in the local noon and afternoon sectors. The night side also shows a peak at local evening sector.

Global maps of GPS positioning errors



Positioning errors reach 60 m during the main phase of ionospheric superstorm of 20 November 2003. During moderate storms, the max error is 18-22 m.

GPS cycle slips during radio-bursts



During solar radio-bursts we observe GPS slips on the whole day side on the both GPS-frequencies. During the event of 6 December 2006, GPS-functioning was disrupted on the sunlit side during 15 min.

GPS cycle slips during radio-bursts