Effect of auroral substorm on GPS slips in the polar ionosphere

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The effect of an geomagmetic substorm on the slips on Global Positioning System (GPS) navigation parameters in the polar region is studied. For the first time, optical data from the all-sky imager, as well as interplanetary magnetic field and magnetometer data are used to complete the analysis of the slips occurrence and to monitor the substorm evolution. Two types of operational slips are considered: (i) instrumental slips including losses in the measured phase of the GPS signal, that is, these slips are of a technical character, reflecting the quality of the electronic components of the radio transmission unit, and can virtually affect the accuracy of navigational positioning and (ii) sharp total electron content (TEC) variations lacking physical explanation or are possibly related to yet unknown processes or phenomena. In the present work, we study in detail the effects of a geomagnetic substorm that occurred on December 23, 2014, between 19:00 and 23:59 universal time (UT), on the slips in phases L1 and L2 as well as TEC slips at high latitudes. We focus on the response of the GPS navigation system to the perturbed ionosphere and study the slips of the main parameters of the GPS navigation signals. To investigate the spatial variability of the GPS TEC measurements, we use in total 4 GPS receivers in the Scandinavian sector, in Tromsø (69.663^{0}N, 18.940^{0}E), Skibotn (69.348^{0}N, 20.363^{0}E), Kiruna (67.857^{0}N, 20.968 ^{0}E) and Sondankyla (64.879^{0}N, 21.048^{0}E). The statistical data analysis for selected stations gives the mean value of the slip probability per satellite.

Our study demonstrates that the operational slips in the GPS navigational signals are mainly related to the auroral particle precipitation that normally occurs during geomagnetic substorms in the polar ionosphere. The auroral particle precipitation produces intensification of optical emissions and therefore a close association of TEC scintillations and aurora can be expected. A rapidly moving auroral arc in the ionosphere can produce a short duration diffractive scintillation

and cause a receiver to lose lock when the GPS ray path crosses the electron density structure associated with the aurora. The GPS frequency L_2 is consistently subject to more slips than frequency L_1 both for quiet and disturbed conditions since the frequency of L_2 is characterized by a smaller signal-to-noise ratio, which makes it a much more sensitive indicator of phase failures. We indicate that the probability of TEC slips is higher than for slips in phase at frequencies L_1 and L_2. It is shown that the auroral substorm leads to a growth in slips L_2 at the stations in Sondankyla and Skibotn with a delay of several hours, which is probably associated with specific features of plasma turbulence originating from magnetic disturbances. This work demonstrates that the maximum of slips is observed during the recovery phase of the auroral substorm. This fact reflects the dynamics of the substorm influence on the ionosphere and, most likely, it is associated with the evolution of plasma inhomogeneities and instabilities in the high-latitude ionosphere excited during the geomagnetic activity. The growth of instrumental slips of the phases of the navigation signals L_1 and L_2 and the TEC calculated on their basis during the recovery of the substorm is shown, that is, the dynamics of the development of the substorm is specified, most likely related to the evolution of a developing and relaxing turbulized ionospheric plasma.

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