Impact of ionospheric disturbances on operation of Global navigation satellite systems at mid- and high-latitudes

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The requirements for the operation stability and accuracy of global navigational satellite systems (GNSS), such as GLONASS and GPS, has permanently increased. As the technologies of satellite and receiving equipment improve, the accuracy and stability of these systems have become gradually depending on the condition of propagation medium, i.e., the ionosphere. Various ionospheric irregularities impact the group, phase, and amplitude characteristics of the GNSS signals. This may result in a slip of the navigational satellite system signals.

In the study, we address GNSS slips of two types. The first type is the radio navigation signal parameter slips, i.e., the cases of slips in measuring the pseudo-range (code slips) and in phase lock (phase slips) of the navigation signal. The second type slips are abrupt unphysical changes in TEC, determined from the GNSS data. We consider morphology of slips of both types at mid- and high- latitude GNSS stations, located in Siberia region, under different geophysical conditions over 2010-2018 period. We also analyze the TEC slips density dependency on the geomagnetic indices, as well as on an integrated parameter for ionospheric variability. As such a parameter, we use WTEC index [1], which reflects the mean intensity of TEC variations over the given periods in the restricted area above the selected GNSS station.

The slip density, when measuring the pseudo-range at high-latitudes for the GLONASS system, is shown to be lower, than that for GPS. At mid-latitudes, on the contrary, the stability of measuring the pseudo-range at the main frequency is higher for GPS, than that for GLONASS. The GLONASS better stability at high latitudes, as compared with that of GPS, may be explained by the difference in the satellite constellation geometry for these systems.

At mid-latitudes, the TEC slips density under quiet geomagnetic conditions practically does not depend on behavior of geomagnetic indices, and does not exceed 12%. At high-latitudes, TEC slips density is generally higher and may reach 50-60% under disturbed conditions.

We revealed a clear dependency of TEC slips density on the WTEC index value, with the similar pattern at mid- and high-latitudes. An increase in the TEC slip density in wintertime occurs 1.5 times faster, then it does in summer. Simultaneously, at high-latitudes, the TEC slips density growth with WTEC increase occurs 2-2,5 times faster, then it does at the mid-latitudes.

For certain periods, when increased level of the slips density were observed, we also calculated positioning errors using the Precise Point Positioning method [2].

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