Source-receiver Ionospheric-scintillation Global Model of the upper Atmosphere (SIGMA): Irregularity Orientation in the Polar Regions and the Impact on GNSS Signal Correlation Processing

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Radio wave signals which propagate through the Ionosphere are vulnerable to scintillation caused by the existence of Ionospheric plasma irregularities. Scintillation, which is the temporal fluctuation in amplitude and phase of a signal, can result in severe channel fading and random phase variations that can interfere with the performance of global navigation satellite (GNSS), communication and radar systems. While various models have been developed for equatorial use, where the nature of the electron density structures are thought to be relatively well understood, there is still a need to advance simulation capabilities for the Polar Regions to better capture the complex anisotropic structures and more effectively evaluate their impact on GNSS system performance. In this paper, we present recent enhancements made to the signal simulation and analysis capabilities of the Source-receiver Ionospheric-scintillation Global Model of the upper Atmosphere (SIGMA) phase screen propagation model. The simulation improvements include the incorporation of Shkarofsky's spectrum to represent the wide range of electron density structures reported at high latitudes, wideband signal propagation to more effectively simulate the legacy and recently available and more advanced GNSS signals, and a spherical wave propagator option to supports the two-way propagation geometries utilized by synthetic aperture radar (SAR) systems. In exercising these new capabilities we compare the new model to the previous version which utilizes a hybrid spectrum to generate the irregularities and a plane wave solution of the forward propagation equation. We also explore the relationship between satellite line-of-sight (LOS) and irregularity orientation in the magnetic north pole region and demonstrate the impact on correlation processing of a GNSS signal. The results from this study provide valuable physical insights into Ionospheric propagation which provide further validation of SIGMA as an Ionospheric propagation model that is well suited for the Polar Regions.