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Effects of geomagnetic substorms on the quality of trans-ionospheric radio waves at high latitudes

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1 Abstract

The accuracy of Global Navigation Satellite Systems (GNSS), at high geomagnetic latitudes is subject to an error that can be detrimental to any industry dependent on precise positioning. GNSS, such as GPS, relies on radio waves that have to travel between a satellite and the receiver through the ionosphere. Disturbed ionospheric conditions, such as during geomagnetic substorms and associated aurora phenomena, can influence the propagation of such waves by diffraction and refraction. This can result in scintillations observed in the amplitude and phase of the received signal. It is thus important for positioning accuracy, to have a good knowledge on the current state of the ionosphere and how it influences the signal. Ionospheric conditions can be deduced from the total electron content (TEC) and scintillation indices, both measured by a ground based GNSS receiver. In addition, by using optical instruments such as All Sky Imagers by looking at the intensity of certain auroral emission lines, the large scale dynamics of the aurora can be monitored.

In this work we relate the substorm dynamics to the quality of the trans-ionospheric radio waves. We use data acquired by a number of different ground based optical All Sky Imagers, as well as data from the GPS scintillation receivers located across Svalbard and northern Norway. We analyze the total electron content (TEC), and scintillation indices (S4 and Sigma Phi) together with the All Sky Imager data taken at wavelength of 557.7nm. We carry out a three tier case study, taking into account different levels of Kp index. Correlating the quality of the GPS signal with the large-scale auroral dynamics, we find that the quality of GPS signals degrades during high geomagnetic activity. Through a detailed study, we relate the scintillation level to the actual auroral phenomena, identifying the dominant scintillation sources for different Kp indices. This study contributes to the future space weather models at high latitudes.