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Investigation of Multi-constellation GNSS Scintillation Caused by Mid-Latitude Ionospheric Irregularities: TEC Measurements in Conjunction with SuperDARN Observations

Mid-latitude ionospheric irregularities are often observed by the Super Dual Auroral Radar Network (SuperDARN) High-frequency (HF) radars. Such irregularities may lead to more significant impact on Global Navigation Satellite System (GNSS) than have been previously considered, for example, causing Radio-Frequency (RF) signal scintillation or even Loss of Lock. The size of ionospheric irregularities which cause scintillation for GNSS signals are on the scale of meters to tens of kilometers. Decameter-scale ionospheric irregularities observed by SuperDARN HF radars may be used to identify GNSS scintillation source regions. Our mid-latitude multi-constellation GNSS observations have shown relatively high scintillation level and large spatial gradient of Total Electron Content (TEC), when the ionospheric piercing points (IPPs) of GNSS satellites pass through ionospheric irregularity areas detected by the SuperDARN Blackstone radar.

In this work, we use the SuperDARN Blackstone radar to detect decameter-scale ionospheric irregularities, and then utilize a multi-frequency multi-constellation GNSS receiver located at Blacksburg, VA, USA to observe the scintillation and measure TEC in conjunction with the radar measurements. Compared with GPS-only scintillation/TEC observations, tracking more constellations greatly increases the number of IPPs to be measured, which improves the measurement opportunities by taking advantage of the currently growing GNSS. Our goal is to analyze the impact on multi-constellation GNSS signals from the mid-latitude ionospheric irregularities detected by the SuperDARN Blackstone radar, with an attempt of integrating multi-constellation GNSS and SuperDARN to study ionospheric irregularities, and characterize the mid-latitude multi-constellation GNSS scintillation based on long-term observations.

The correlation characteristics between the GNSS scintillation and the mid-latitude ionospheric irregularities observed by the SuperDARN Blackstone radar are evaluated by statistical analysis. Because the severity of RF signal scintillation is frequency and power dependent, the ionospheric scintillation on different frequency bands of GPS, Glonass and Galileo constellations are analyzed and evaluated. Multi-constellation GNSS TEC measurements are undertaken simultaneously with the scintillation measurements, to detect carrier phase TEC cycle slip and

measure the spatial gradient of TEC. Therefore the movement of GNSS satellites (moving IPPs) can be potentially used to estimate the boundary of small-scale ionospheric irregularity regions identified by SuperDARN radars. Global TEC maps from MIT Madrigal Database are also used as a reference to estimate the boundary. Also extended observational data reveal more characteristics of mid-latitude GNSS scintillation, including the diurnal variation, magnitude distribution as well as the sensitivity between phase scintillation and amplitude scintillation.