Space weather at Mid-Latitudes: Survey of GPS scintillations during Solar Cycle 24

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Global Positioning Systems (GPS) is an invaluable technological system that has generated over >$3B in economic benefit alone (in the US) [1], and its economic value is increasing year over year. The engineering requirements for GPS services are tightening with advancing technologies, making the end users more vulnerable to GPS interruptions. For instance, it is estimated that one day of GPS outage would incur more than $1B in losses [1]. Therefore, the areas of dense population at mid-latitudes are disproportionately more vulnerable to GPS outages caused by error sources such as the ionospheric space weather. It is still challenging to forecast scintillation because it is not well understood how mid-latitude scintillation is distributed and how scintillation is related to density structures. To overcome this issue, we utilize 1-Hz (high-rate) GPS receiver network in the U.S. sector, deployed and operated by UNAVCO inc., to characterize occurrence and spatiotemporal morphology of ionospheric structures scintillating the GPS signals at mid-latitudes. We use intensity scintillation index derived from carrier-to-noise-ratio (CNR) of GPS L1-signal as the scintillation diagnostic.

The research presented in this presentation is a result from the NASA Living With a Star Institute 2019: “Space Weather Impacts on GNSS Radio Occultations at Mid-Latitudes.” We analyzed available ground-based observations of GPS scintillating events and put them in the context of geophysical drivers associated to the ionospheric space weather. We present a survey using the high-rate GPS receivers from 8 years between 2012 and 2020. We found 9 events that produced GPS scintillations at mid-latitudes. All events occurred during geomagnetic storms. The storm’s Dst was ranging between -204 nT and -51 nT, with a median of -131 nT, and median Kp 7^-. A superposed epoch analysis did not reveal any additional characteristic geomagnetic drivers producing the mid-latitude scintillation, compared to storms without scintillation?.

The majority of the scintillation events originated at low-latitudes. Namely, spatiotemporal morphology of the ionospheric irregularities suggests the equatorial plasma bubbles (EPB) as the ionospheric mechanism scintillating structures. In these cases, the EPBs expanded beyond 35-degree MLAT, in several cases beyond 42 degrees which equates to expansion beyond L=2 at the equatorial plane. In the other cases, we find the mid-latitude ionospheric structures strikingly similar to the first report of the GPS scintillation observed by *Ledvina et al. (2002)* [2]. The latter events indicate possible influence or coupling with high-latitude ionosphere, hence the plasmasphere – inner magnetosphere.

We discuss possible future consequences to GPS services at mid-latitudes, and how changing geomagnetic field and the upcoming solar maximum might impact the ionospheric space weather.

References

[1] AC O’Connor et al. (2019), Economic Benefits of the Global Positioning System (GPS). RTI International, 0215471. Available from: https://www.rti.org/sites/default/files/gps_finalreport.pdf.
[2] B Ledvina, J. J Makela, and P. Kintner. (2002). “First Observations of intense L1 amplitude scintillations at midlatitude,” *Geophysical Research Letters*, **29**, 14, doi:10.1029/2002GL014770.