Investigation into Geomagnetic Storms and Ionospheric Scintillation
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Introduction

Identifying the relationship between solar activities, ionospheric irregularities and consequently ionospheric scintillation has inspired numerous research efforts due to the insight it provides on impacts of space weather on daily life. Solar activities such as geomagnetic storms cause ionospheric irregularities. When radio waves travel through these irregularities, they experience rapid fluctuations in the signal phase and amplitude. Such fluctuations, known as ionospheric scintillation, have great consequences in radio wave based technology such as the Global Position system as it can cause loss of lock. As such, industries that are dependent on the accuracy of radio wave based technology such as aviation, agriculture and mining are especially sensitive to the impacts of space weather events that directly affect the ionosphere.

Therefore, radio signal data from the Global Navigation Satellite System (GNSS) is sensitive to the impacts of space weather events that directly affect the ionosphere. Consequently, ionospheric scintillation has inspired numerous research efforts due to its impacts on radio wave based technology such as the Global Positioning System (GPS) as well as TEC in specific time intervals measured in universal time (UT). The methodology adapted from the case study of a geomagnetic storm obtained from World Data Center at Kyoto University and NOAA for data on geomagnetic activity throughout the day will continue to be applied in analyzing all geomagnetic storms between August 2018 and August 2019. As seen in Figure 1, there is an interruption in the radio signal that causes it to fluctuate between 5 dB and –5 dB as observed in 3 different PRNs on August 26th, 2018. These fluctuations seem to occur between 6 UT and 12 UT. Rapid fluctuations in radio waves tend to take place when there are irregularities in the ionosphere. To confirm whether the radio signal was passing through an irregularity in the ionosphere, the Total Electron Content plots were analyzed. On the same day, between approximately 6 UT and 12 UT, significant decrease in the TEC is observed.

In addition, abrupt changes in IMF Bz’s polarity from northward to southward can cause solar wind’s magnetic field and earth’s magnetic field to merge. This merging leads to a discharge of magnetic energy which causes the geomagnetic storms observed. The IMF Bz Plot shows a significant shift from positive Bz, indicating northward polarity at approximately 5 UT to negative Bz at 6 UT, indicating a southward polarity. This leads one to conclude that a geomagnetic storm developed during this time.

Furthermore, geomagnetic activity measurements were consulted. KP index ranges from 0 to 9, 0 indicating quiet activity while 9 indicates extreme geomagnetic storm. The highest value of KP index of 9 was recorded during the times radio signal fluctuations were observed. The AE plot also confirms intense geomagnetic activity throughout the day.

Future Work

The methodology adapted from the case study of January 31st, 2019 has proved effective. The method will continue to be applied in analyzing all geomagnetic storms between August 2018 and August 2019. After further analysis is complete with multiple days highlighting the relationship between geomagnetic storms and ionospheric scintillation in mid latitude, a manuscript with compiled data analysis can be created.

Continue analyzing GNSS scintillations in mid latitude region.

Acknowledgement.

To NASA’s DSOCVR spacecraft, World Data Center at Kyoto University and NOAA for data on geomagnetic storms.

Office of Undergraduate Research at Embry Riddle Aeronautical University.

Results

The month of August 2018 was selected as an initial point since intense geomagnetic activities were observed during this time period. The power, phase and amplitude of radio signals throughout each day of the month, as well as the recorded total electron content were plotted.

Analysis of the plots showed signal perturbation between 6 and 12 UT on August 26th, 2019. Sudden spikes in Power and Phase on PRNs 1, 2, and 30 are observed at 12 UT, 9 UT and 13 UT respectively as seen in Figure 3.

The TEC plots from Galileo showed a gradual drop from 30 TECU to 24 TECU between 8 and 12 UT while GPS 8 showed a similar trend dropping from –6 TECU to -20 TECU. Both Galileo 12 and GPS 8 confirm a significant decrease in the total electron content as seen in Figure 4.

Further more the Auroral Electroject (AE) graph shows significant activity throughout the day ranging from -150 to +150. A negative Bz at 6 UT, indicating a southward polarity is observed. The AE plot also confirms intense geomagnetic activity throughout the day.

The geomagnetic activity measurements showed that a Kp index of 9 was recorded between 6 UT and 9 UT. Further more the Auroral Electroject (AE) graph shows significant activity through out the day ranging from 500 nT to -2000 nT.

Finally the z component of the interplanetary magnetic field (IMF Bz) increases from 0 nT to 15 nT between 6 to 12 UT. A negative Bz is observed at 6 UT and then again from approximately 16 UT to 24 UT.

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