Evaluating the Relationship between Thunderstorms and Ionospheric Scintillation

D. Koshy, N. Gachancipa, S. Steele, C. Thakrar, J. Herrera, D. Mekonnen, M. Priore, K. Deshpande [PS]

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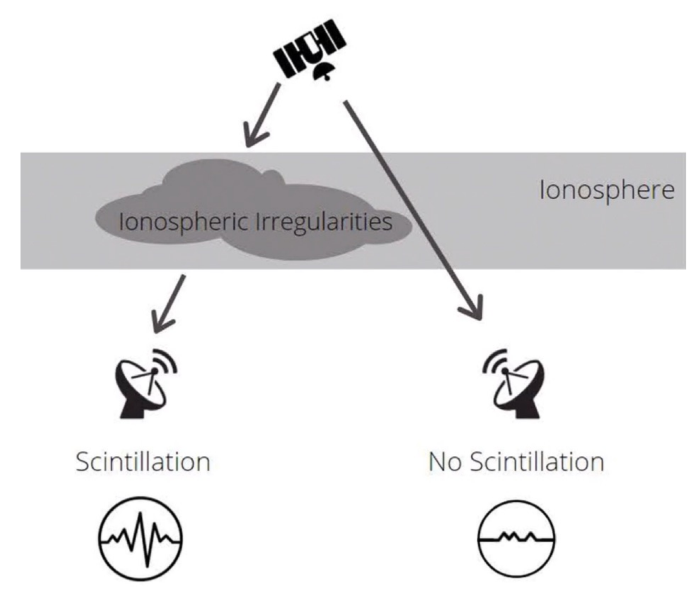
INTRODUCTION

IONOSPHERIC SCINTILLATION

- Global Navigation Satellite Systems (GNSS), such as the Global Positioning System (GPS), provide time and location measurements for a variety of industries.
- GPS receivers are devices which can lock to incoming GNSS signals. Some receivers, such as the GPStation-6, can measure ionospheric scintillation, serving as a remote-sensing instrument.
- The ionosphere is a region in the Earth's upper atmosphere where solar radiation ionizes atoms, resulting in free electrons floating and interacting with electromagnetic signals crossing the atmosphere (NASA, n.d.).
- Ionospheric scintillation occurs when a satellite signal interacts with free electrons in the ionosphere, causing the signal to present rapid fluctuations in its phase and/or amplitude. Strong scintillation can result in communication outrages.

Figure 1. Ionospheric scintillation is caused by irregularities in the upper atmosphere, which disturb GPS signals. The irregularities are formed by free electrons as a product of solar radiation.



THUNDERSTORMS AND SCINTILLATION

- This project is the continuation of a 2019 study which investigated the correlation between ionospheric scintillation and thunderstorms in mid-latitudes (Herrera, Priore, Mekonnen, & Deshpande, 2019).
- The ongoing study aims to complement the findings of the 2019 study, in which it was determined that lightning strikes had a correlation with scintillation events observed in data collected by GPS receivers.
- Lightning strikes are of special interest, since they can cause ionospheric irregularities.

OBJECTIVE

The purpose of this project is to study the correlation between thunderstorms and ionospheric scintillation. The study focuses on the impact that lightning strikes may have on the propagation of signals from global navigation satellite systems.

The ionospheric data collected is collected by GPS receivers operated by the Space Physics Research Lab (SPRL). The data is parsed and analyzed using the Embry-Riddle Ionospheric Scintillation Algorithm (EISA).

METHOD

DATA COLLECTION

- The NovAtel GPStation-6 receivers used by the GNSS team collect ionospheric scintillation and total electron content (TEC) data in Daytona Beach, FL. The receivers have continuously collected data since the summer of 2017.
- The data collected for this project corresponds to four thunderstorms that occurred between August and October 2020, in the following dates.
  1. August 6th and 7th
  2. September 13th and 14th
  3. September 9th and 10th
  4. September 27th and 28th

Figure 2: NovAtel GPStation-6 GNSS Ionospheric Scintillation Receiver

DATA ANALYSIS

- The data is being analyzed using the Embry-Riddle Ionospheric Scintillation Algorithm (EISA), a state-of-the-art model developed at the Space Physics Research Lab to process ionospheric data.
- The method consists of the following process:
  1. Identify and document the dates and times in which thunderstorms were observed in the region.
  2. Identify the satellites that were in the GPS receiver's field of view during the time of the thunderstorm.
  3. Parse the data for the dates and times identified in step 1 for the satellites found in step 2, using EISA.
  4. Plot the power and phase of the high-rate data collected by the receivers. Peaks in the data often indicate the presence of ionospheric scintillation.
  5. Identify the exact times at with lightning strikes occurred in the region of interest (~ a 10 km radius around the location of the GPStation-6 receivers).
  6. Identify correlation between peaks in the data and lightning strikes.
  7. Compare the power and phase plots to their counterparts in days when thunderstorms were not present, to rule out that the scintillation events were not the product of multipath.
  8. Determine if there was any geomagnetic activity occurring the day of the event, to rule out that the observed scintillation events were the product of geomagnetic storms, by discarding the presence of spikes in the DST geomagnetic index.

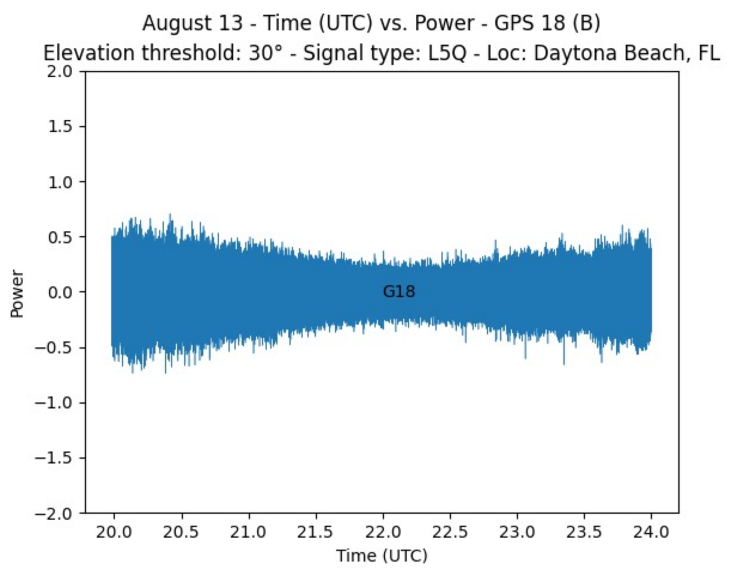


Figure 3: High-rate power of a GPS satellite 18 signal, generated using the EISA algorithm.

Figure 4: Disturbance Storm Time (DST) index showing no geomagnetic activity in August 2020. Source: Kyoto University.

RESULTS

- The team has found significant presence of scintillation during the thunderstorm of August 6th, 2020, which occurred between 12 AM and 2 AM UTC.
- The following plots show the power of the signal of GPS satellites 10, 20, and 21 during the 6 August 2020 thunderstorm. The time is shown in UTC, which corresponds to the early morning of August 7th.

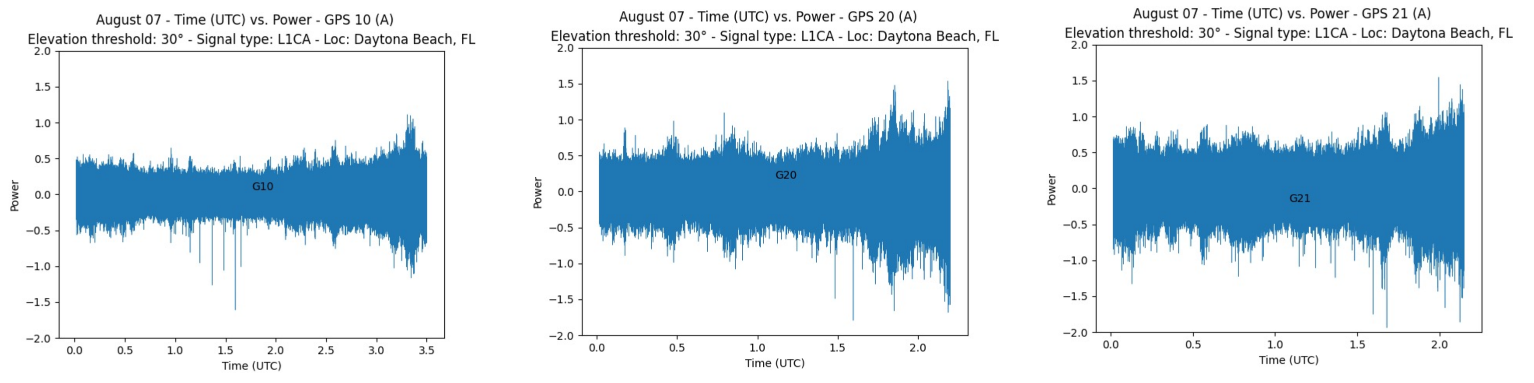


Figure 5: High-rate data plots of GPS satellites 10, 20, and 21 during the August 06 storm in Daytona Beach, FL. The storm occurred between 8 and 10 PM local time (12AM – 2AM UTC time).

- Scintillation is observed at 1:30 AM UTC (9:30 PM local time), when sudden disturbances in the power of the signal are observed. The observed scintillation is consistent across data from multiple satellites.
- The high-rate data of August 7th was compared to data from the previous day (Figure 6), to rule out the presence of multi-path (signal interference). Moreover, it was determined that the disturbance was not the product of geomagnetic storms, since there was minor geomagnetic activity occurring on the date of the thunderstorm.

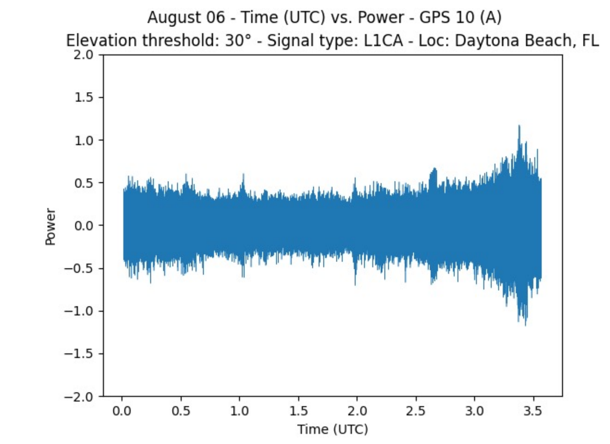


Figure 6: High-rate data plots of GPS satellite 10 between 8 and 10 PM local time on August 5th (12AM – 2AM UTC on August 6th), a day before the thunderstorm occurred. No major disturbances (sudden peaks or troughs) are seen in the figure at around 1:30 AM UTC.

CONCLUSIONS & FURTHER WORK

- A correlation between thunderstorms and ionospheric scintillation was identified in the data from August 7th, confirming the results from previous studies carried out by the GNSS team.
- The results from EISA need to be compared to meteorological data, to determine if specific lightning strikes may have been the cause of the observed disturbances. The team is currently working with other researchers to obtain lightning strike data.
- In order to further verify the findings, the team will analyze ionospheric scintillation data from other thunderstorms in the Daytona Beach area.

REFERENCES

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