Tropospheric Scintillation Signatures: Observations of the Possible Effect Thunderstorms Have on GPS Signals

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Objective

- Study if the lightning produced by a thunderstorm can affect the ionosphere in mid-latitudes.
- Investigate if lightning can create strong enough ionospheric structures to generate scintillation.

Introduction

GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS)

- There are 31 satellites used for the Global Positioning System (GPS), which is one of the various networks of satellites that makes up the GNSS.
- Rapid modification of radio waves, otherwise known as scintillation, impacts and disrupts GPS signals.

THUNDERSTORMS

- Tropospheric disturbances (i.e. thunderstorms and lightning) can cause disturbances in the ionosphere.
- Variations in total electron content (TEC) have correlated with notable thunderstorm activities in the area.
- Some thunderstorms can reach over 10 km into the stratosphere as seen in Figure 1.

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PLOTTING HIGH RATE DATA AND SKY PLOTS

- Converted GPS data from binary to more accessible data.
- Developed a Python code to filter data and produce Sky plots for plotting a satellite’s location (Figure 6) and a MATLAB code to graph high rate data for scintillation analysis (Figure 2).

DETERMINING CANDIDATES

- Found date of thunderstorms and matching high rate GPS data.
- Studied corresponding graphs to find matching thunderstorm times.

Lightning data, as seen in Figure 3, is then analyzed when scintillation is seen to happen during or near the time of a thunderstorm.

Method

- Looked for peaks in the graphs which are commonly attributed to scintillation as seen in Figure 2.
  1. Ruled out multipath for cause of scintillation by comparing “normal day” to a possible scintillation day.
  2. All scintillation graphs are accompanied by a “normal day” graph to show the extent of the scintillation.

Discussion and Future Work

- Significant scintillation was observed on August 9 and 10, 2018 in the mid-latitudes before the thunderstorm was directly overhead; the cause is currently undetermined, but data, as seen on Figures 2 and 4, may suggest the lightning that happened during these times may have caused the observed scintillation.

Other possibilities that cause scintillation were eliminated (i.e. multipath, geomagnetic storms)

1. No significant correlation found between the change in the Disturbance Storm Time (DST) index, as shown in Figure 5, and the scintillation found on August 9 and 10.

2. Solar activity was very low and geomagnetic field activity remained in quiet levels from August 8-10.

Cloud tops of this case reach into the stratosphere and potentially produce lightning that affects the ionosphere.

For August 9, Figures 6 and 7 reveal that the satellite was travelling near the thunderstorm region.

The above-mentioned factors lead to the conclusion that lightning strikes caused in the thunderstorm of August 9, 2018 had a likely correlation to the observed scintillation of the obtained GPS signal.

Further analysis is needed to determine whether this is the only case or if it is a consistent phenomenon. Whether individual lightning strikes or an entire thunderstorm is required to cause significant scintillation will also be studied more, as well as if scintillation happens before, during, or after the storm.

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