HF Doppler Observations of Traveling Ionospheric Disturbances in a WWV Signal Received with a Network of Low-Cost HamSCI Personal Space Weather Stations

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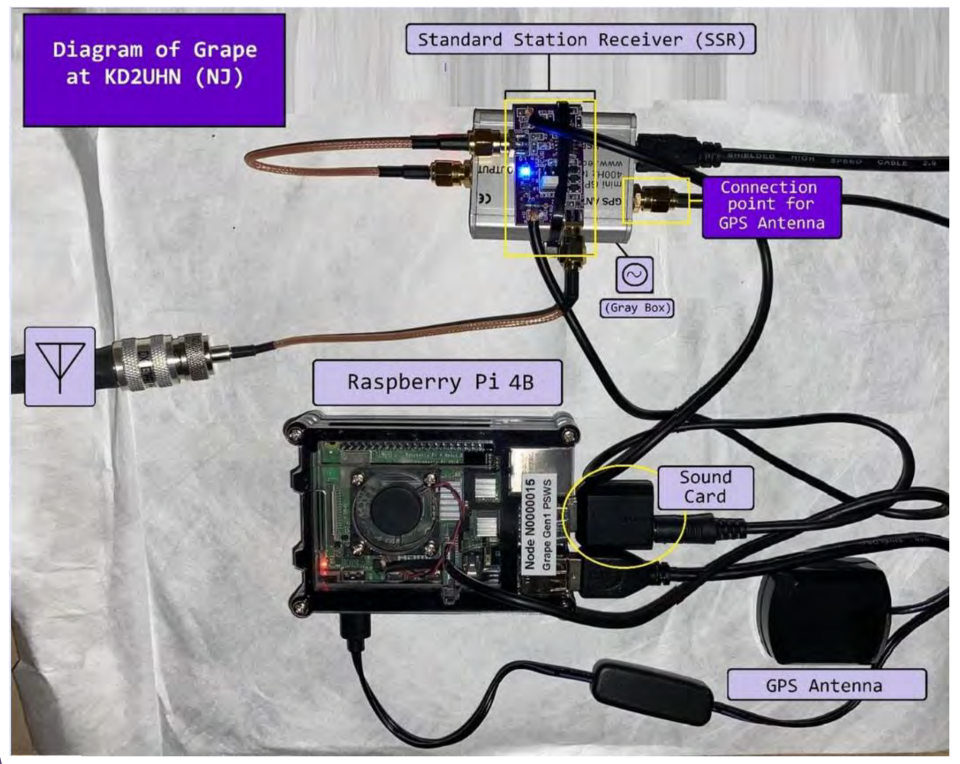
Abstract and Introduction

Traveling Ionospheric Disturbances (TIDs) are quasi-periodic variations in ionospheric electron density that are often associated with atmospheric gravity waves. TIDs cause amplitude and frequency variations in high frequency (HF, 3-30 MHz) refracted radio waves. The authors present observations of TIDs made with a network of Ham Radio Science Citizen Investigation (HamSCI) Low-Cost Personal Space Weather Stations (PSWS) with nodes located in Pennsylvania, New Jersey, and Ohio. The TIDs were detected in the Doppler shifted carrier of the received signal from the 10 MHz WWV frequency and time standard station in Fort Collins, CO. Using a lagged cross correlation analysis, we demonstrate a method for determining TID wavelength, direction, and period using the collected WWV HF Doppler shifted data.

(FIGURE 1) The image to the left shows a map of WWV to the 3 Grape Receivers discussed in this poster. There are currently 15 Grapes set up and running in the USA, but the authors are interested particularly in these 3 due to their geographical location, which is beneficial to studying the propagation direction of TIDs

(FIGURE 2) The picture to the right is of the 15 MHz antenna from WWV. The 10 MHz antennas are of a similar design. WWV is a radio station located in Fort Collins, Colorado. It is well-known as a United States Frequency Standard which is extremely accurate as to what frequency it is transmitting on. The station runs in the HF (High Frequency) range of the radio spectrum. WWV transmits at 2.5 MHz, 5 MHz, 10 MHz, 15 MHz, 20 MHz, and experimentally on 25 MHz. For the purposes of this poster, we will consider the transmission that occurs at 10 MHz. (History of Radio Station, 2021)



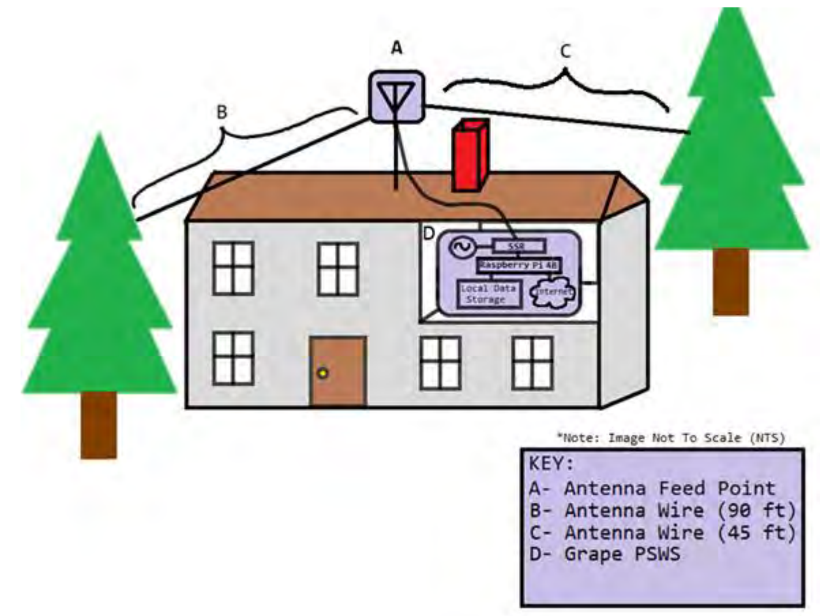
(FIGURE 3) The image to the left shows the Grape

- Leo Bodnar mini GPS Discipline Oscillator
- Sound card
- custom receiver board
- Raspberry Pi 4B

This image depicts the setup and orientation of the Grape located in Northwest New Jersey. As outlined in the picture, the coaxial cable from the antenna connects to the Standard Station Receiver (SSR). The GPSDO also connects to the SSR. The SSR connects through a sound card to the Raspberry Pi 4B single board computer which allows the data to be transmitted and stored on the internet. The data collected each day can be accessed using a VPN into the Raspberry Pi 4B. That makes it accessible from remote locations.

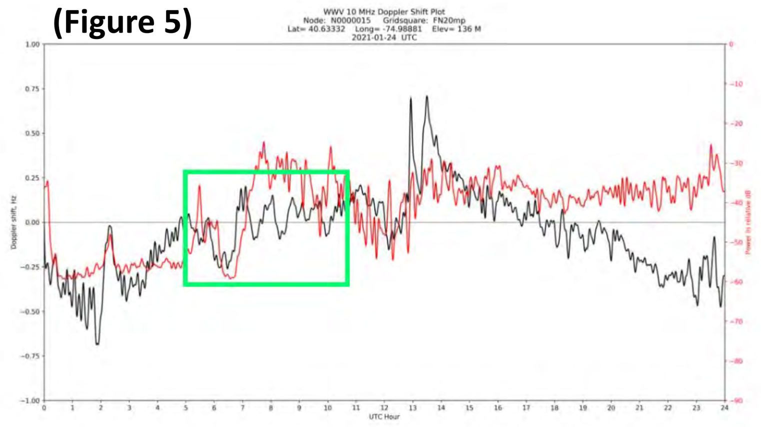
Method/Experiment

(FIGURE 4) The picture shown to the right depicts the setup of the Grape. The Buckmaster OCF Dipole Antenna is mounted roughly 30 feet high, on top of the roof. The wires (notated as B and C in the image) connect to the antenna feed point and are an approximate cumulative length of 135 feet (one side is 90 feet, the other is 45 feet long). There is about 25 feet of coaxial cable running from the antenna to the Grape. The orientation of the Grape at point D can be seen with a clearer depiction in Figure 3.

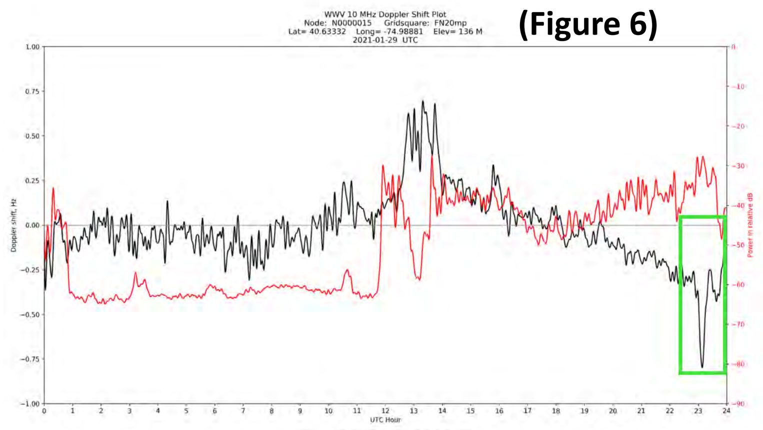


Data and Analysis

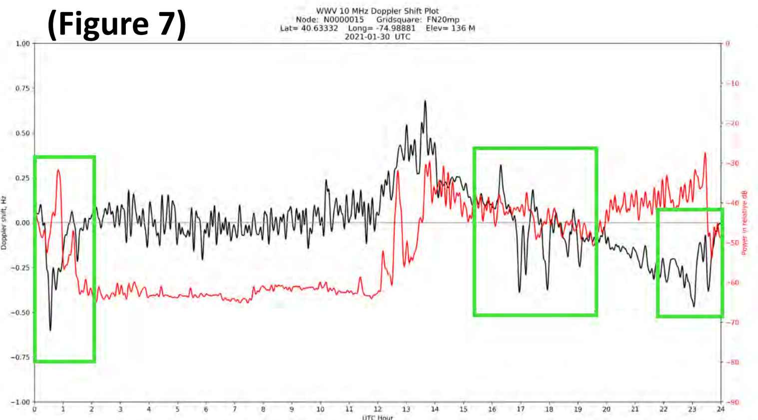
(Figure 5)



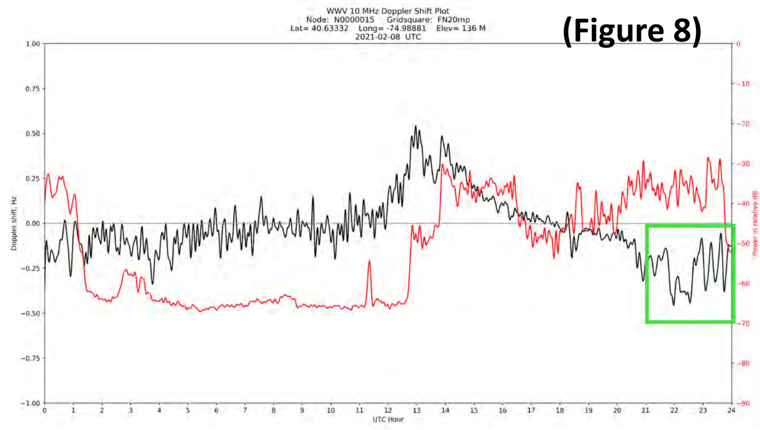
(Figure 6)



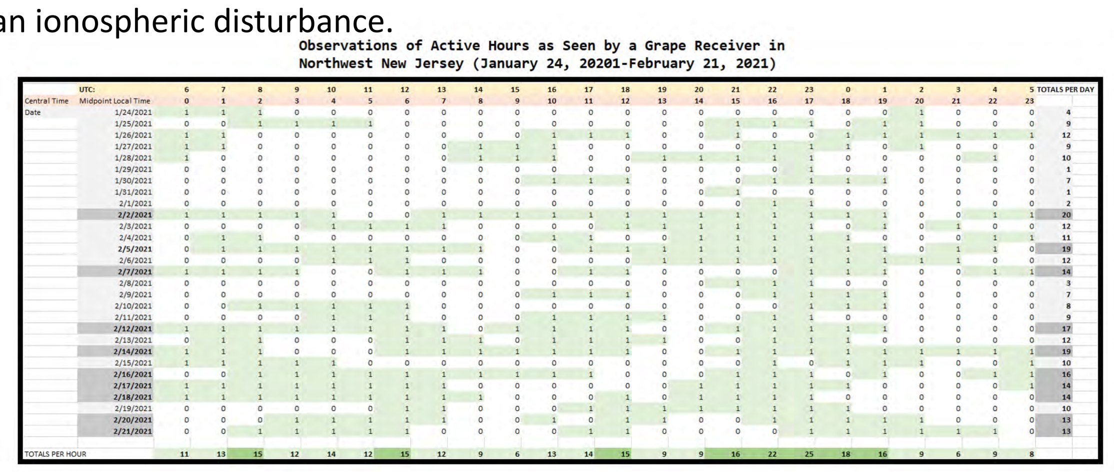
(Figure 7)

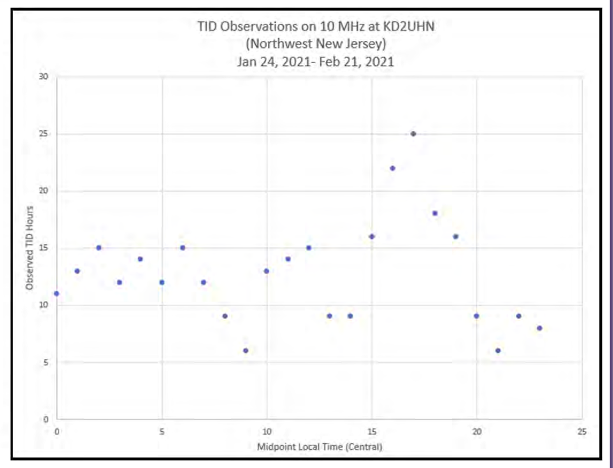


(Figure 8)



At 00:00 UT each day, the Grape is set to automatically output a graph showing the data frequency variation data collected for that day. The graphs depicted above represent data collected from the Grape located in Northwestern NJ. The black line represents the change in the received WWV carrier frequency from 10 MHz in Hz. The red line represents measured signal strength. This graph provides a visual understanding of what the Grapes are looking to find: ionospheric disturbances. Some examples of these disturbances are outlined above in green boxes. The box outlines a sinusoidal movement detected in the received frequency by the Grape. This movement can be attributed to an ionospheric disturbance.





(FIGURE 9) The figure shown above shows the collection of data from the Grape over a time period in early 2021. The hours with "1" were considered to be TID active hours, while those with "0" were considered to be quiet. Active hours are those that have a distinct change in Doppler Shift (the black line) that is very close to +0.25 Hz or greater. If the shift was close to 0.25 Hz, but not followed by a sinusoidal pattern, and did not appear to be distinctly different from the preceding and following hours, then that hour was not noted as an active hour. The author selected only times that had oscillation periods of about 15 minutes or greater. Active hours are frequently followed by other active hours, forming a sinusoidal-like shape. Note that each day, during sunrise there is a sudden peak in the measured Doppler Shift. During sunset, there is a sudden drop in the Doppler Shift. This observation is consistent with those discussed by other authors (Cerwin, 2020). It is also important to consider that these are very early results and so there is limited data to consider when making these observations.

(FIGURE 10) shows a graphical distribution of the data shown in figure 9.

Conclusion

In conclusion, The Grape Personal Space Weather Station (PSWS) is making observations consistent with those expected of Traveling Ionospheric Disturbances. A statistical study of Traveling Ionospheric Disturbance (TID) occurrence was conducted with observations recorded from January 24th to February 21st 2021. While the results are relatively early, they suggest TID signatures are most prevalent during the hours of 21:00 UTC to 02:00 UTC (or 15:00 Midpoint Local Time- 20:00 Midpoint Local Time).

Future Work

In the future, the authors plan to expand the time range of observations used in this statistical study as well as refine the statistical study methodology. The authors will explore the physical mechanisms for TID production by combining the data presented in this poster with data from other sources to help diagnose methods of TID production. In a matter of years, the authors will be working with physical models to further the understanding of TIDs. In addition, other authors are consistently proposing physical mechanisms for TIDs and the authors of this poster will see if those suggestions match the data that is collected by the Grapes.

Furthermore, the authors will continue to investigate the observations of several other Grapes located around the United States. This includes the Grapes currently placed in Pennsylvania, Ohio, and New Jersey. The authors hope to use the observations made by these Grapes to aid them in developing a method to better predict the direction of TID propagation. They hope to connect with other researchers so that they can work together to develop an accurate and reliable method to track and predict the direction of TID travel.

References

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