Signatures of Space Weather in the NJIT V1 Grape Low-IF Receiver

Tiago Trigo[1], Gareth W. Perry[1], Sabastian Fernandes[1], John Gibbons[2], Nathaniel A. Frissell[3], Ham Radio Science Citizen Investigation

1- Center for Solar Terrestrial Research, NJIT

2 - Department of Electrical Engineering, Case Western Reserve University

3 - Department of Physics and Engineering, The University of Scranton

E-mail: tft5@njit.edu, ttrigo2003@gmail.com

P20

Introduction

- High Frequency (HF; 3-30 MHz) signals are used for long range communication by reflecting those signals off the bottom side of the Ionosphere.
- Analyzing Doppler residuals from these reflected signals can be used to study Ionospheric scintillation and signal propagation.

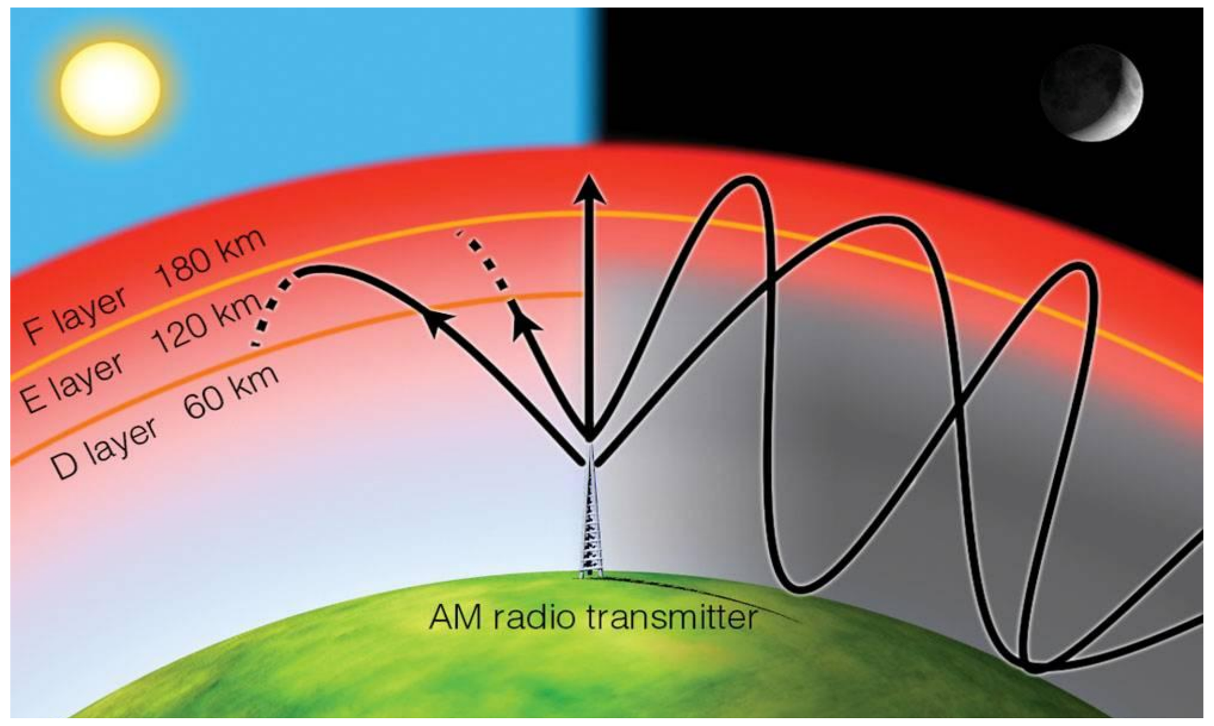

Figure 1: A diagram representing signal propagation of AM radio waves through the Ionosphere at different times of day. Signals tend to reflect at lower altitudes during the day, however the frequency of these signals also dictates when they reflect. North Vermont University Meteorology[1].

- The Ham Radio Science Citizen Investigation (HamSCI) community has produced a low cost personal space weather station (PSWS) called the V1 Grape Low-IF (Intermediate Frequency) Receiver.
- The V1 Grape is used nationally and internationally by universities, citizen scientist, and volunteers in order to study the effects of space weather events on the Ionosphere.
- The Grape monitors a single frequency along a singular path continuously. (Collins[2] et al., 2023).
  - SuperDARN radars typically have a 1 minute cadence.
  - Ionosondes typically have a 3-15 minute cadence.

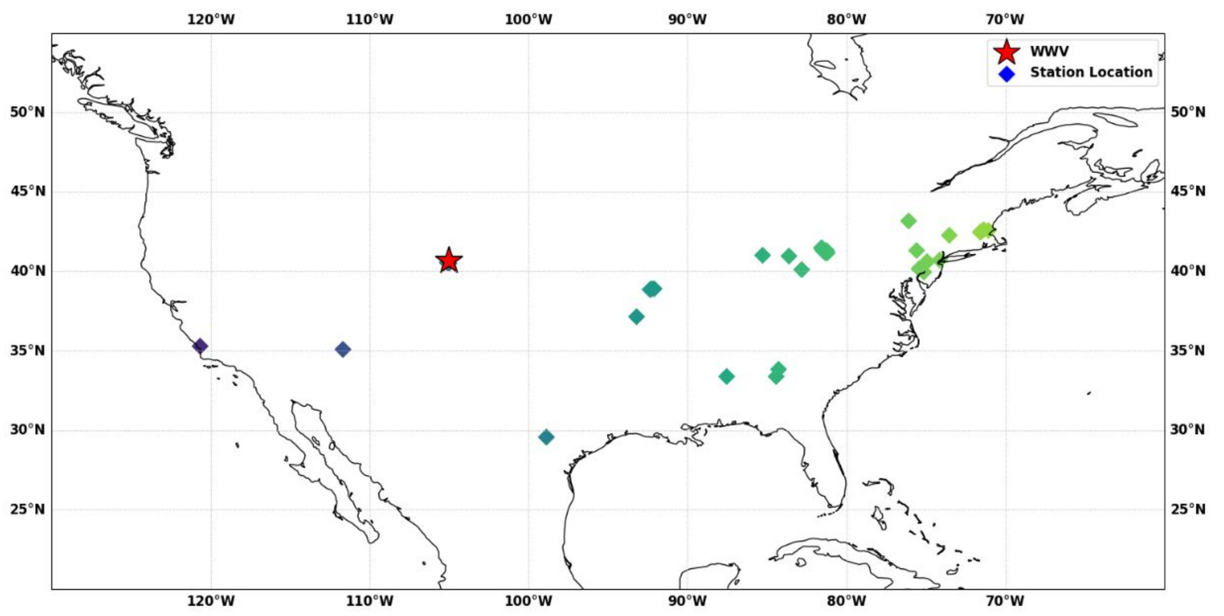

Figure 2: A diagram of active V1 Grapes as of 2022. The red star represents the WWV station that outputs the 10 MHz signal received by all Grapes. All other points are the active V1 Grapes. Collins[2] et. al.

Objectives

- Investigate the behavior of HF signals with respect to voltage peaks and power over time.
- Identify periods of scintillation from moments of extreme propagation.
- Demonstrate the viability of voltage data for Ionospheric studies.

Methodology

- A V1 Grape Low-IF Receiver was installed with a 30m inverted vee antenna (see Figure 4) tuned to 10MHz at the Newark Institute of Technology (NJIT) in Newark, New Jersey.
- The 10MHz signal is generated by the NIST radio station WWV in Fort Collins, Colorado.
  - GNSS disciplined oscillator produces an extremely stable signal.

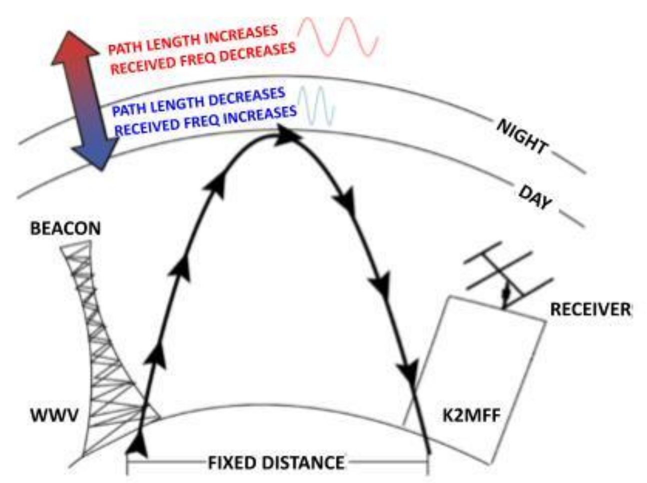

Figure 3: A diagram representing the path which the 10 MHz signal travels from the WWV beacon in Fort Collins, CO to the K2MFF receiver at NJIT in Newark, NJ. The ionosphere exposure to sunlight during sunrise is associated with a blueshift for HF signals, and vice versa (redshift) for sunset. Recreated from Collins[2] et al.

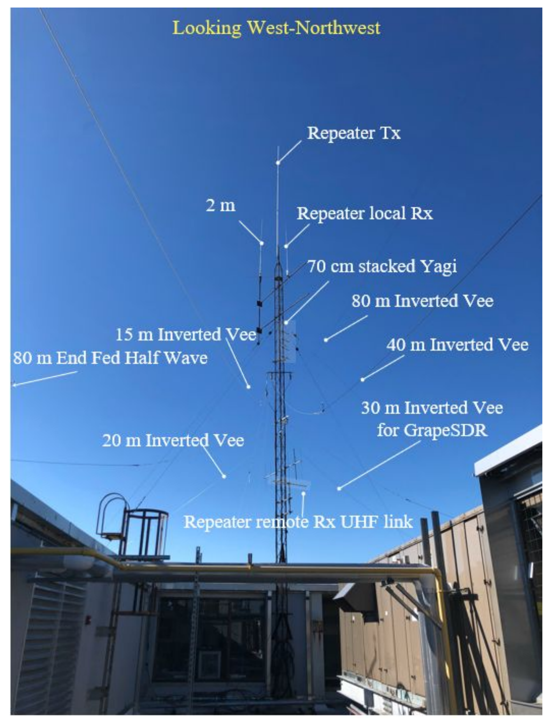

Figure 4: A photograph of the K2MFF receiver antenna referenced in Figure 2. Taken by Gareth Perry.

- The Grape outputs two sets of data, changes in frequency and voltage peaks per second.
- Relative Power is our received voltage peaks converted to the decibel scale using 20log10(Vpeak).

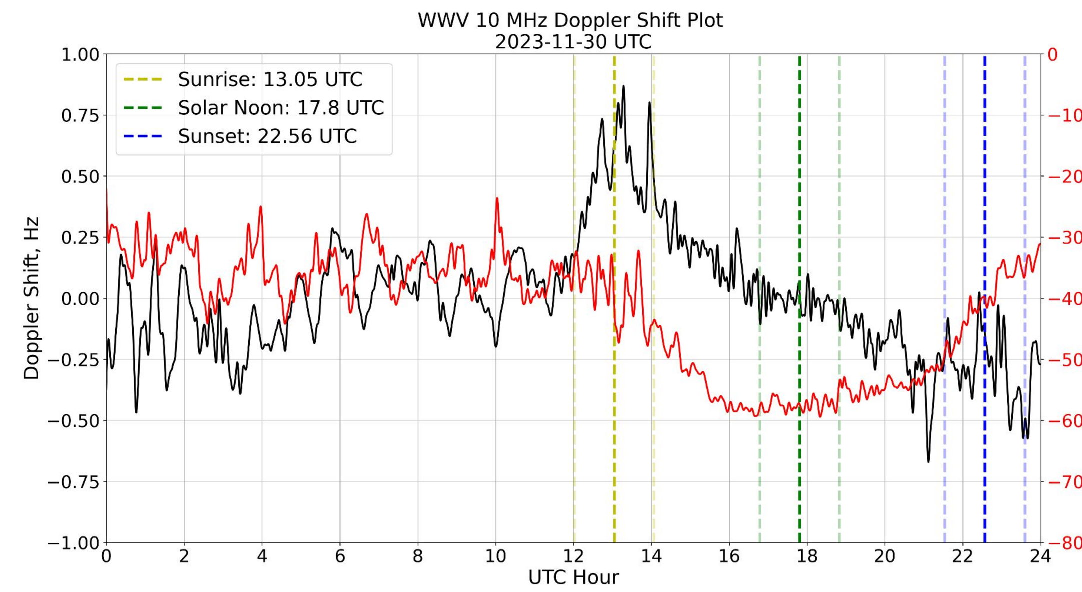

Figure 5: Doppler Shift (Black) and Relative Power (Red) distribution for November 30, 2023. The yellow vertical line is UTC Sunrise, green is Solar Noon, and blue is Sunset. The bold lines are the midpoint between the WWV and Grape, to the right is NJ, and left is Colorado.

Results

- Voltages are converted to a decibel scale to the immense difference in the lowest and highest peak values.

October 2023 Annular Eclipse

- During the October 2023 solar eclipse there is a significant rise in received voltage.
  - The eclipse started at 10:30 PDT for Colorado which correlates to 16:30 UTC.

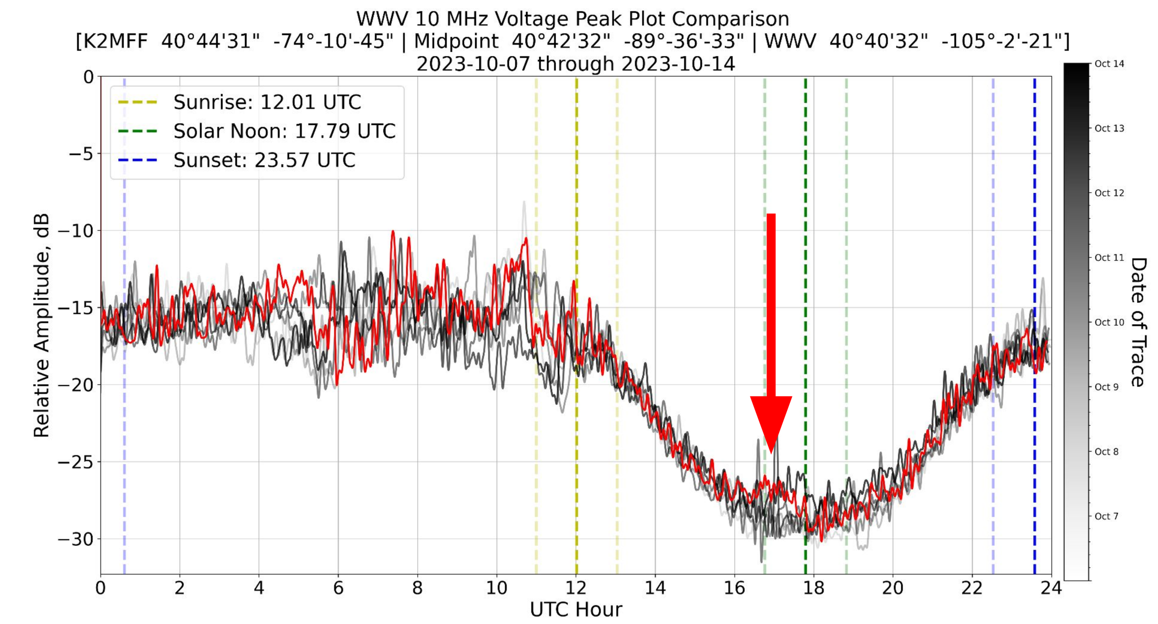

Figure 6: Voltage readings from Oct 7th to Oct 14th 2023, with the 7th being the lightest color and the 14th represented by the red trace.

November 2023 Flares

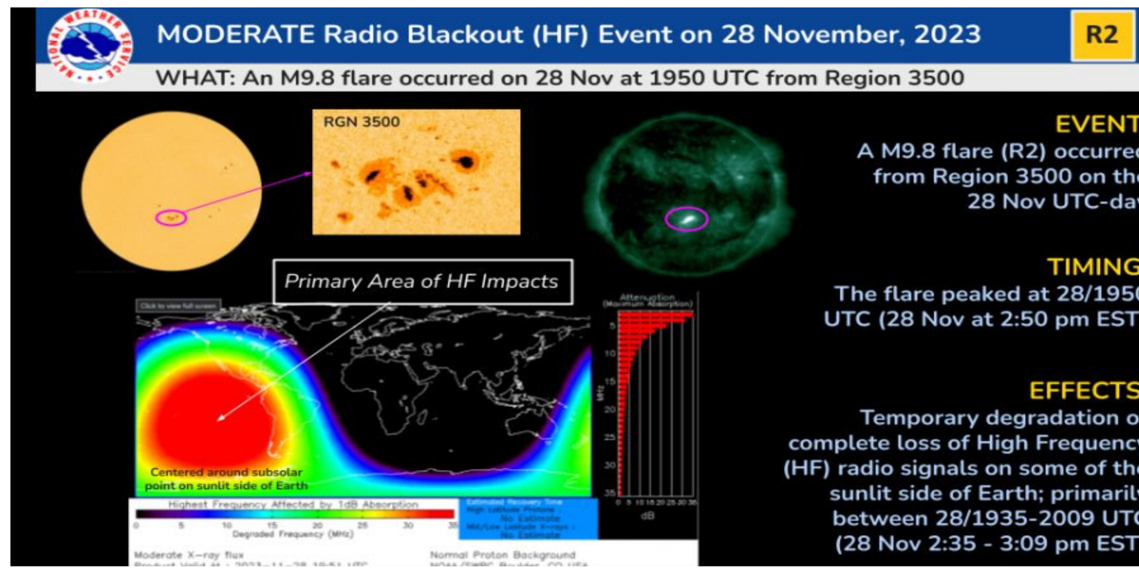

Figure 7: A diagram explaining the HF blackouts observed on November 28th 2023 from an M class 9.8 Solar Flare peaking at 1950 UTC. Space Weather Prediction Center[3].

- On November 28, 2023 an M9.8 flare caused a mass ionospheric shift which increased the amount of signal propagation.

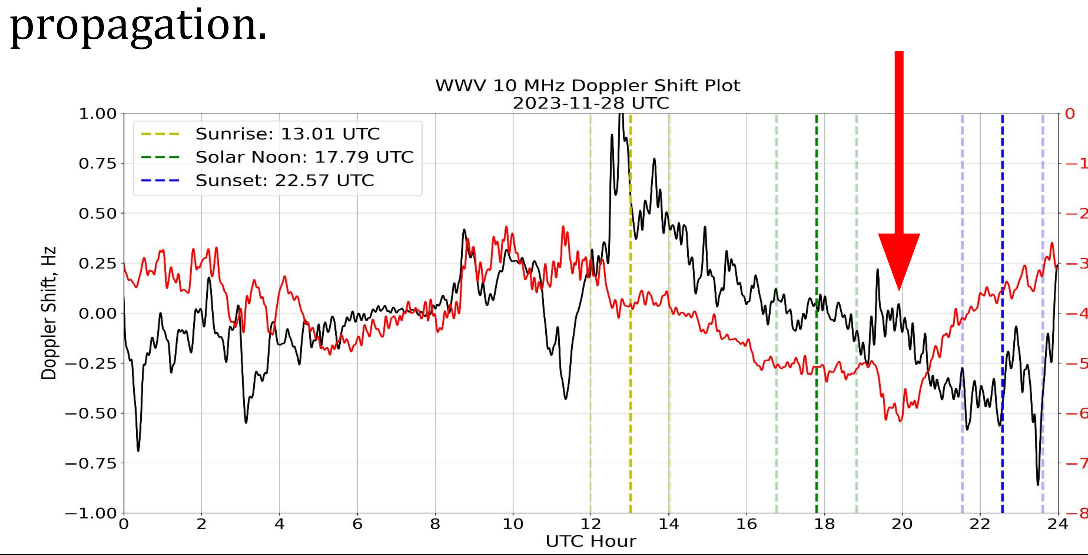

Figure 8: Relative Power readings from Nov 28th flare denoted by the red trace. The flare reached its peak at 1950 UTC, causing a decrease in received power and a perturbation in Doppler shift, a common sign of flares.

Discussion

- Throughout the night the peaks follows a mostly rayleigh distribution until it crosses sunrise in which it is a majority exponential distribution.
- This coincides with the distribution shown which has rapid changes in magnitude pre-sunrise and a rapid growth post-sunrise.

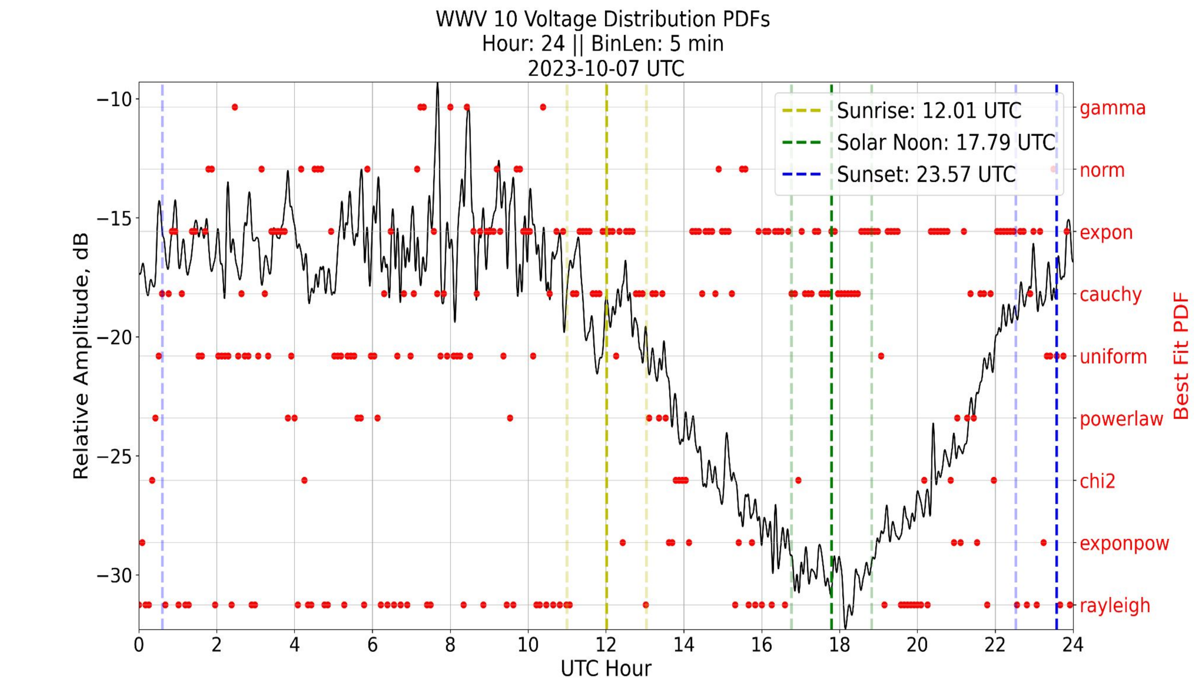

Figure 9: A graph distinguishing which algorithm is the best fit per 5 minutes in a 24 hour period on October 7, 2023.

Conclusions

- The V1 Grape is a great low cost receiver for research based on Ionospheric scintillation.
- Voltage peaks are a viable method for analyzing Ionospheric anomalies from geophysical phenomena.
- Solar Flares and Eclipses are some of the few space weather events that can be detected by PSWS.

Future Work

- Looking at data over a wider range of time such as a year in order to observe trends.

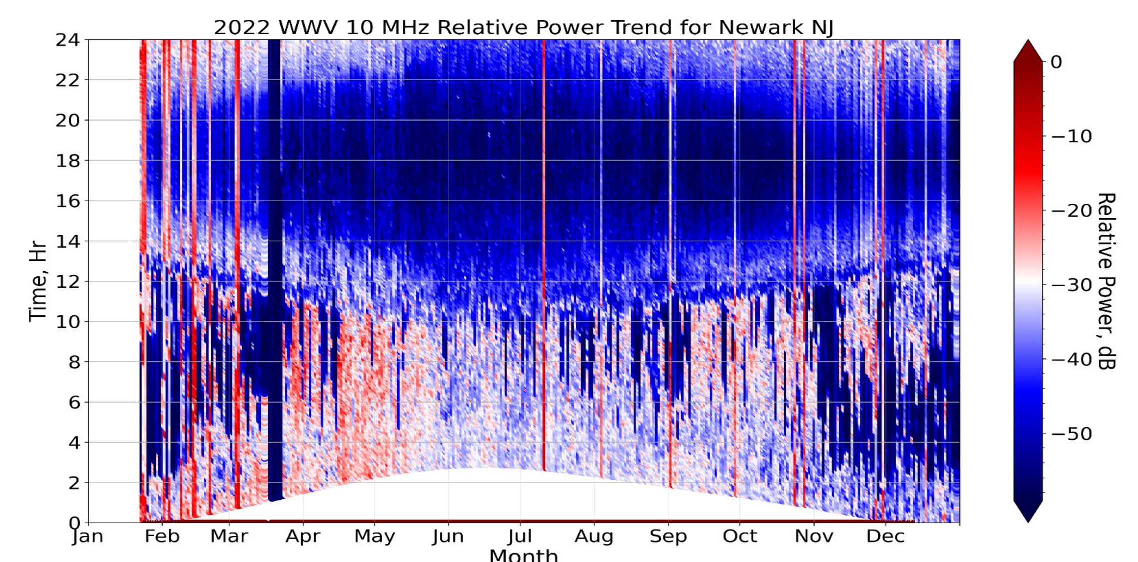

Figure 10: Day by Day distribution of relative power over the year of 2022. Still needs to be adjusted for time shift and missing corrupted data from January.

- Looking into the prototype V2 Grape Multi-Channel that can receive multiple frequencies.
  - New Grape V1 DRF receivers that digitize data.

Acknowledgements

This work was completed with the support of Dr. Gareth Perry and Sabastian Fernandes from the Center for Solar-Terrestrial Research at NJIT. A further thank you to the HamSCI community for their extensive work on the V1 Grape. We also acknowledge the support of NASA grant 80NSSC23K1322, and NSF grants AGS-2002278, AGS-2230345, AGS-2230346.

New Jersey Institute of Technology

References

[1] The Ionosphere and Radio Wave Propagation. North Vermont University. https://apollo.nvu.vsc.edu/classes/met130/notes/chapter1/ion2.html

[2] Collins, K., Gibbons, J., Frissell, N., et al. : Crowdsourced Doppler measurements of time standard stations demonstrating ionospheric variability, Earth Syst. Sci. Data, 15, 1403–1418, https://doi.org/10.5194/essd-15-1403, 2023.

[3] R2 (Moderate) HF Radio Blackout Event on November 28, 2023. Space Weather Prediction Center. https://www.swpc.noaa.gov/news/r2-moderate-hf-radio-blackout-event-28-november-2023