Seasonal Climatology of Ionospheric Variability with MSTID Periods Observed Using HamSCI Grape HF Doppler Receivers

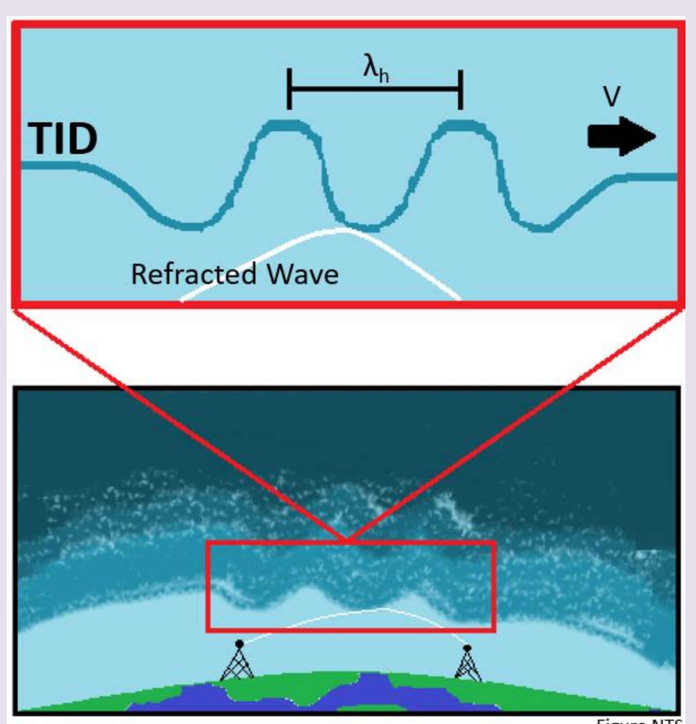
Veronica Romanek[1], Nathaniel A. Frissell[1], William Liles[2], Kristina Collins[3], John Gibbons[3]

[1]University of Scranton, [2]HamSCI Community, [3]Case Western Reserve University

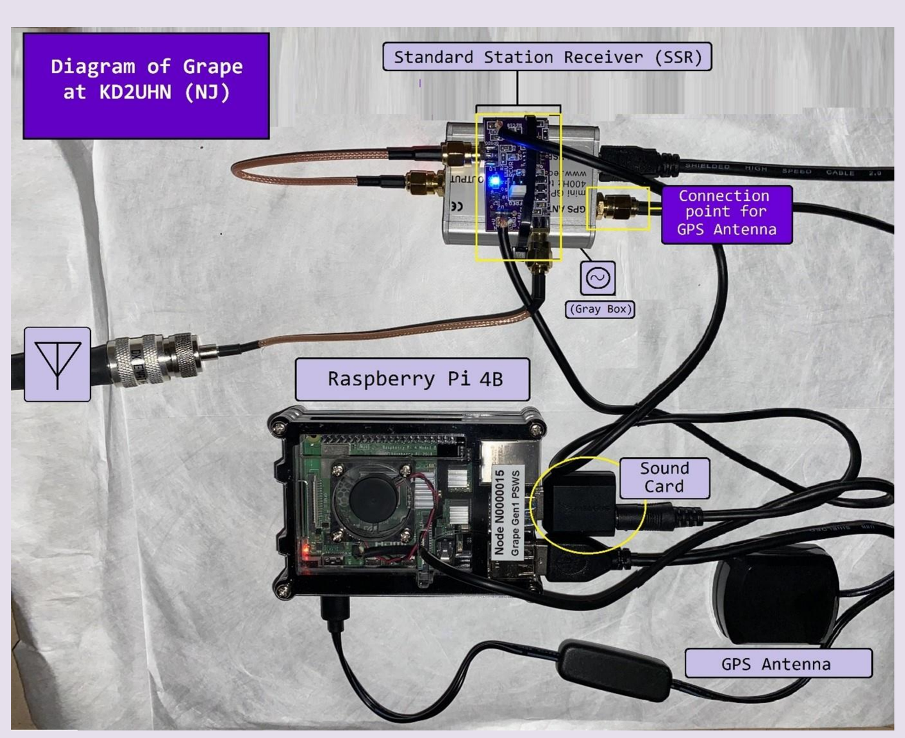
Abstract

Medium Scale Traveling Ionospheric Disturbances (MSTIDs) are quasi-periodic variations in ionospheric electron density that are often associated with atmospheric gravity waves. MSTIDs cause amplitude and frequency variations in radio waves that refract off the ionosphere. Typical MSTIDs exhibit wavelengths of 50-500 km and periods of 15-60 minutes. The authors present an analysis of observations of MSTIDs made with a network of Ham Radio Science Citizen Investigation (HamSCI) Low-Cost Personal Space Weather Stations (PSWS), located throughout the continental United States. The MSTIDs were detected in the Doppler shift of the received carrier of radio station WWV. WWV is a frequency, and time, standard transmitting station located near Fort Collins, Colorado, USA. By analyzing the Power Spectral Density (PSD) of oscillations received by the Doppler-shifted carrier wave, we demonstrate a method to determine the seasonal variation climatology of MSTIDs. Initial results suggest enhanced MSTID activity is observed at dawn and dusk, as well as through the pre-midnight period. Dawn and dusk MSTID enhancements are consistent with Atmospheric Gravity Waves (AGWs) generated by the terminator.

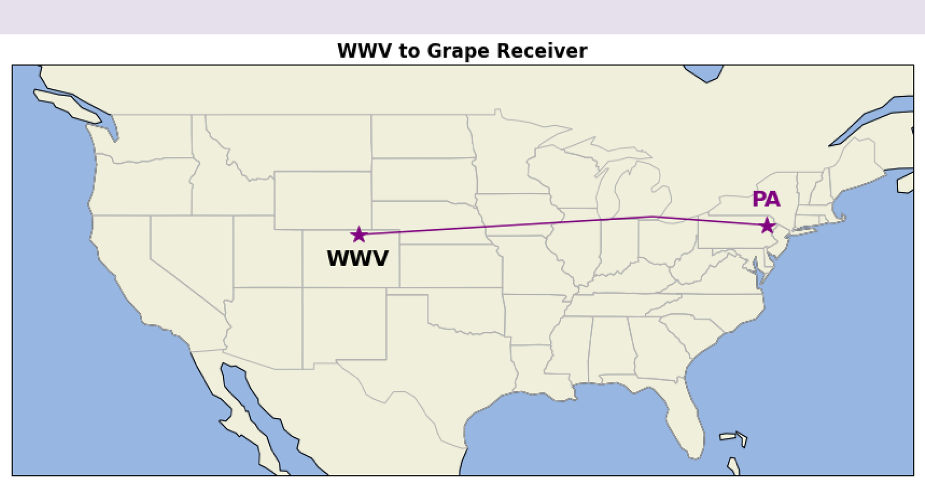
Introduction



(FIGURE 1) This image (*left*) portrays a diagram of a Traveling Ionospheric Disturbance (TID). Note that radio waves that refract off the ionosphere can be used to detect TIDs. This poster presents a method that can be used to determine their propagation direction, depicted by the black arrow near the top of the figure. Lambda indicates the TID wavelength and V indicates the TID velocity. This poster presents data specific to Medium-Scale TIDs (MSTIDs), which are characterized by periods between 15 and 60 minutes, phase velocities between 100 to 250 m/s, and wavelengths of 50 to 500 km.



(FIGURE 2) This image (*right*) depicts the setup and orientation of the Grape Personal Space Weather Station (PSWS). A coaxial cable from an antenna connects to a Standard Station Receiver (SSR) along with a GPSDO. 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. The data presented in this poster is collected by a Grape PSWS

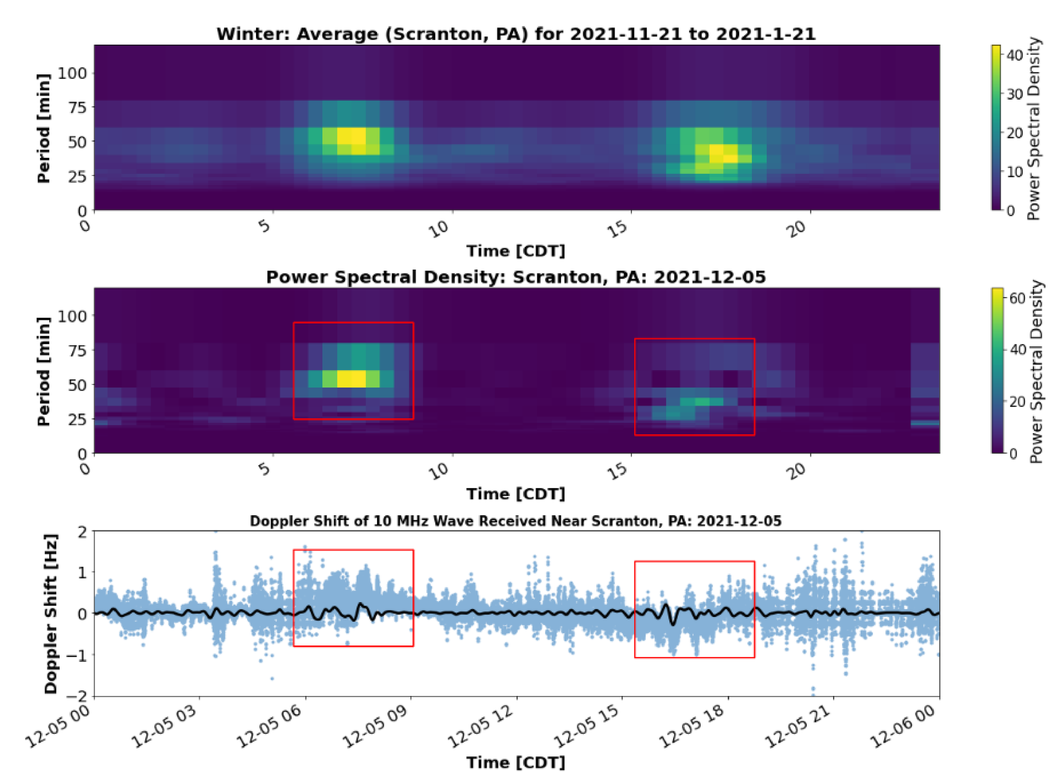


(FIGURE 3) This image (*left*) shows the 2D great circle path between the transmitter (WWV) and a Grape Personal Space Weather Station (PSWS) located near Scranton, PA, which is the Grape PSWS being used to collect the data presented in this poster. WWV transmits on a number of frequencies. This poster looks at data collected specifically from the 10 MHz transmission, which leaves the receiver, refracts off the ionosphere, and is eventually received by the Grape PSWS. As the ionosphere moves, this will be received as Doppler-Shift from the 10 MHz transmitted wave.

Method

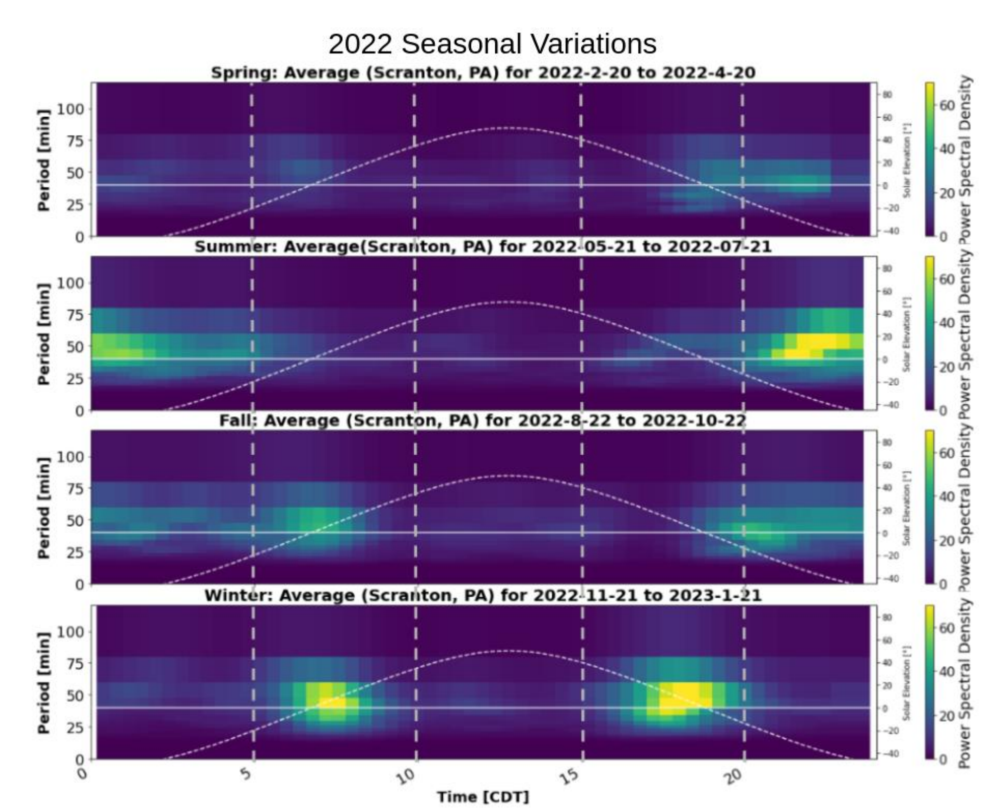
In order to explain the process used to obtain the seasonal average plots below, a case study was performed on one day. This day was chosen for no particular reason other than the fact that strong MSTID-like signatures were observed on this day.

(FIGURE 4)

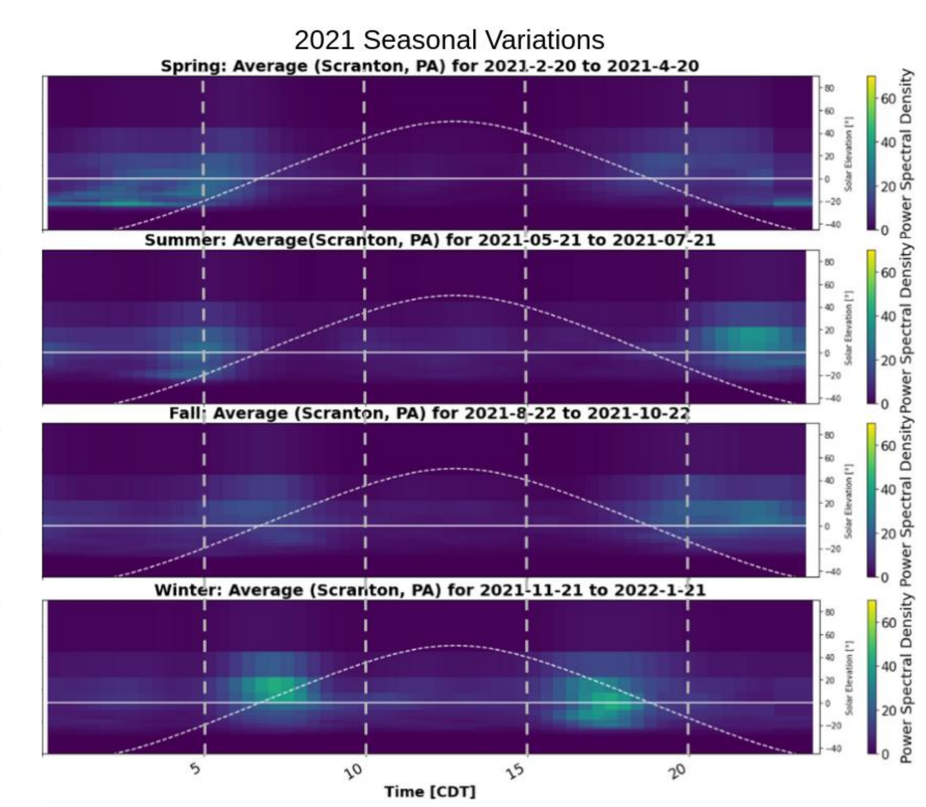


- **The top plot** in Figure 4 shows the average Power Spectral Density (PSD) for each respective season. This shows when MSTID-like signatures are most commonly detected by the Grape PSWS located near Scranton, Pennsylvania.
- **The middle plot** in each Figure 4 shows the PSD for the respective day labeled above it.
- **The bottom plot** in Figure 4 shows the corresponding Doppler-shifted received carrier wave for that day. The red boxes outline the relationship between a strong PSD and strong oscillations from the bottom plot in the figure.

(FIGURE 5)



(FIGURE 6)



Data Analysis

The data suggests increased MSTID activity around sunrise and sunset for each respective season in the years 2022 and 2021. The scale has been normalized to compare like units of PSD between the years 2022 (left) and 2021 (right). The difference in the intensity of PSD is likely due to the fact that each dataset accounts for the seasonal average of PSD values. Thus, any very strong or very weak MSTID-like oscillations could potentially be overpowering the rest of the data set. However, in order to know for sure why there is a difference in intensity, further analysis would need to be performed.

Conclusion

In conclusion, a method has been developed to distinguish between seasonal variations of Medium-Scale Traveling Ionospheric Disturbance (MSTID) activity. An analysis was performed on data collected by a HamSCI Grape Personal Space Weather Station (PSWS) located near Scranton, PA. The particular data shown in this poster is from 2021. The varying seasonal behavior suggests increased periods of MSTID activity around sunrise for each respective season, with other varying hotspots at different times of the year. Such hotspots include increased MSTID activity during Spring between midnight and around 8:00 AM EST, as well as after 8:00 PM EST; increased MSTID activity during the Summer around midnight, 6:00 AM, and after 8:00 PM EST; hotspots for MSTID activity around midnight, between 5:00 AM -10:00 AM, and after 8:00 PM EST during the Fall; and increased MSTID activity between 6:00 AM – 10:00 AM and 4:00 PM – 8:00 PM EST.

Future Work

In the future, the results presented in this poster could be expanded upon by applying this method to data collected from different Grape Personal Space Weather Stations (PSWS). This method could also be furthered by considering the results used from observing Doppler-Shifted carrier frequencies other than 10 MHz.

References

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veronica.romanek@scranton.edu

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