Personal Space Weather Receiver

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Abstract: The impact on the ionospheric conditions from space weather is a difficult subject to study as it requires many datapoints from geographically separate locations. The Ham Radio Science Citizen Investigation (HamSCI) project developed by the University of Scranton and Case Western Reserve University seeks to enable this geographically dispersed data collection by providing the design of small radio receivers and a common database to aggregate the data. The radio transmission from the National Institute of Standards and Technology's WWV station in Fort Collins, Colorado, provides a known signal that nodes can simultaneously receive. As the height of the ionosphere changes, the frequency received will be shifted up or down due to the Doppler effect. The difference in WWV's frequency and the received frequency paired with the total transmit time allows researchers to gather data on the current conditions of the ionosphere. The receiver consists of an HF antenna, a GPS Disciplined Oscillator (GPSDO), a signal mixer board, and a Raspberry Pi.

Background: PSWS Grape 1 Receiver

WWV in Colorado transmits a steady 10 MHz carrier frequency which refracts off the ionosphere and is received by K3GCC's receiver in Western Pennsylvania. The Doppler shift and power level is detected by the Grape 1 Receiver. The area of the ionosphere that we examine is above Montezuma, Iowa, the midpoint between Fort Collins, CO and Grove City, PA.

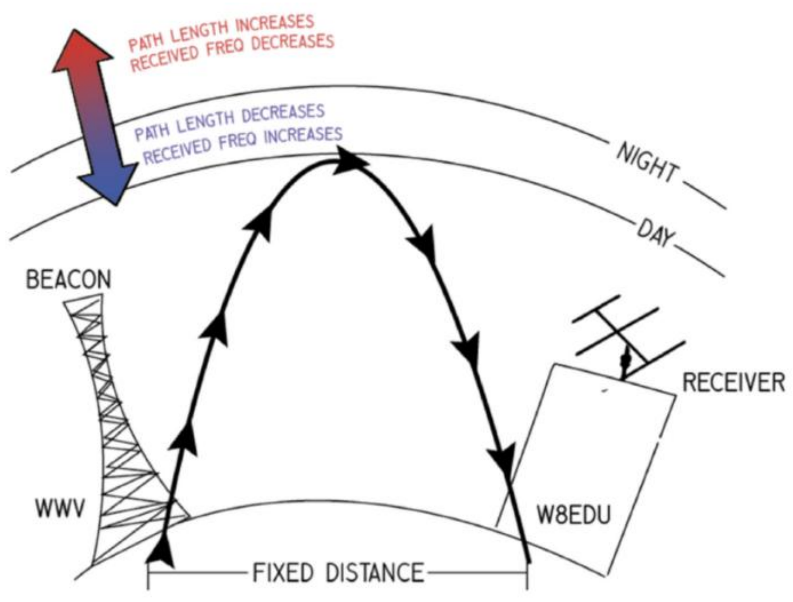

Figure 1. Doppler Shift from WWV
(Collins, et al. HardwareX, 2022)

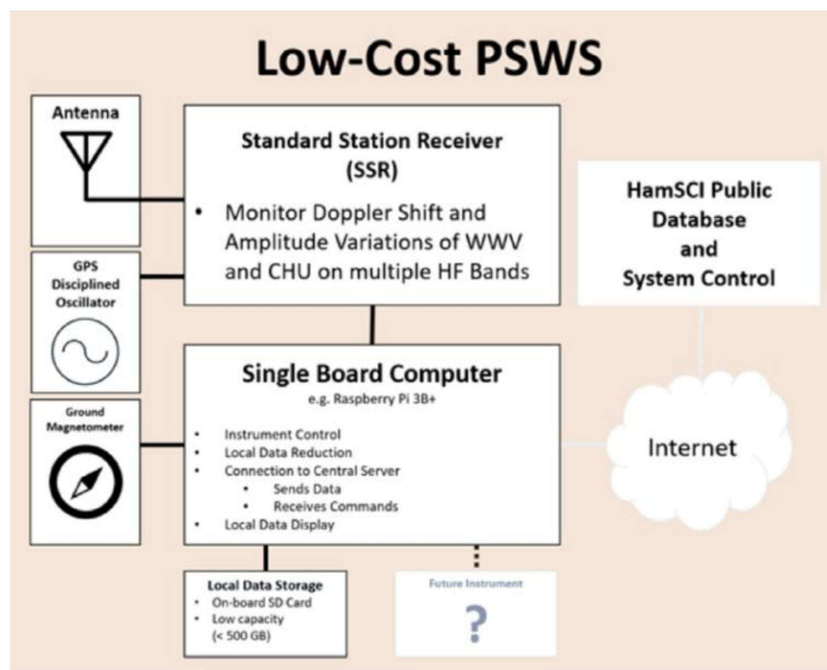

Figure 2. Grape 1 Setup
(Collins, et al. HardwareX, 2022)

Experimental Setup: Grape 1

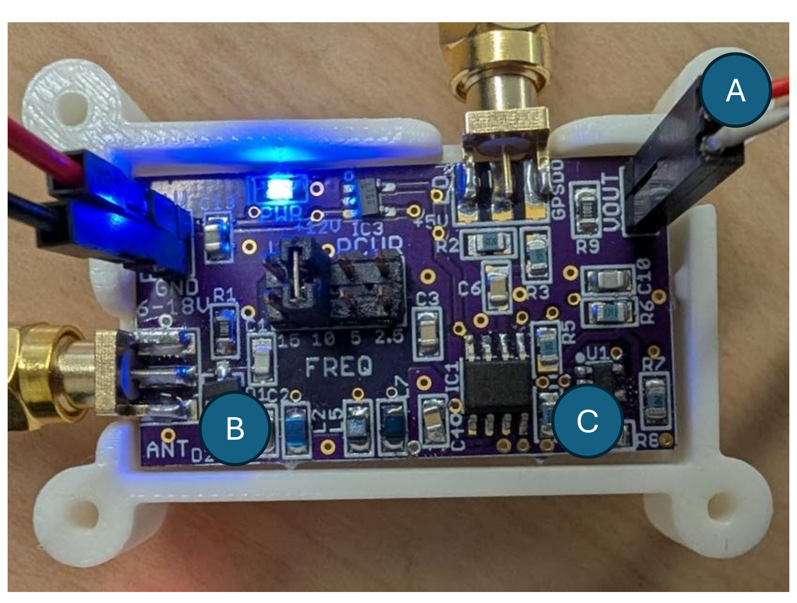

Figure 5. Mixer Board. The mixer combines the signal from the GPSDO (A) and the HF antenna (B) and sends the data to the Pi. The SA612AD mixer chip (C) combines the signals

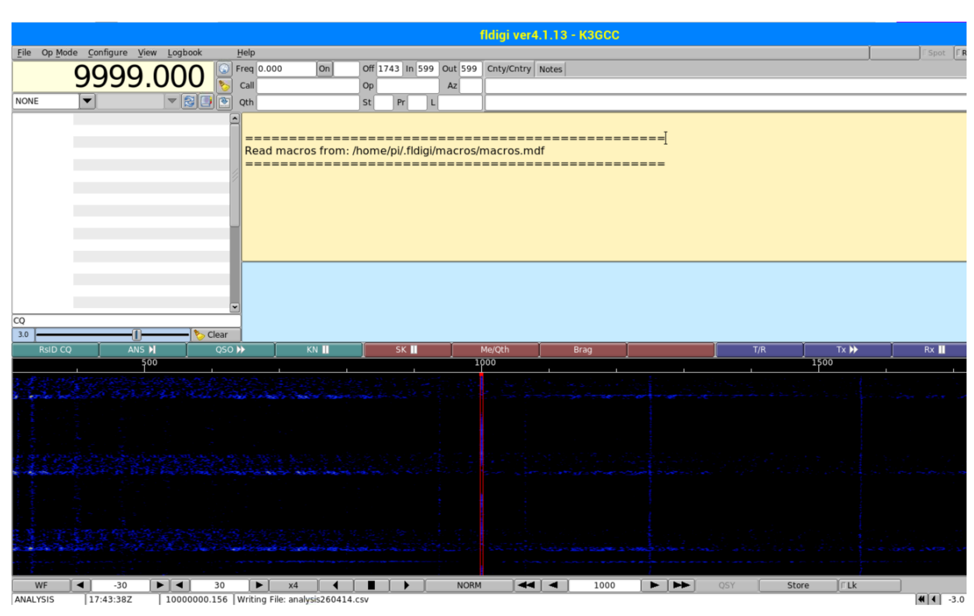

Figure 6. Fldigi. Fldigi is an open-source soundcard modem designed for Amateur Radio applications. It is currently configured to receive the 10 MHz WWV carrier.

Experimental Setup: Grape 1

The Grape 1 consists of four main components: The antenna (Figure 4A), Raspberry Pi (Figure 3C), the GPS Disciplined Oscillator (GPSDO, Figure 3A), and the mixer board (Figure 5). The Raspberry Pi utilizes the Fast Light Digital (Fldigi) SDR to receive WWV's carrier signal (Figure 6). At the end of every day the Pi exports a CSV file and plot of day's space weather data. The data is uploaded to HamSCI's database hosted by the University of Alabama.

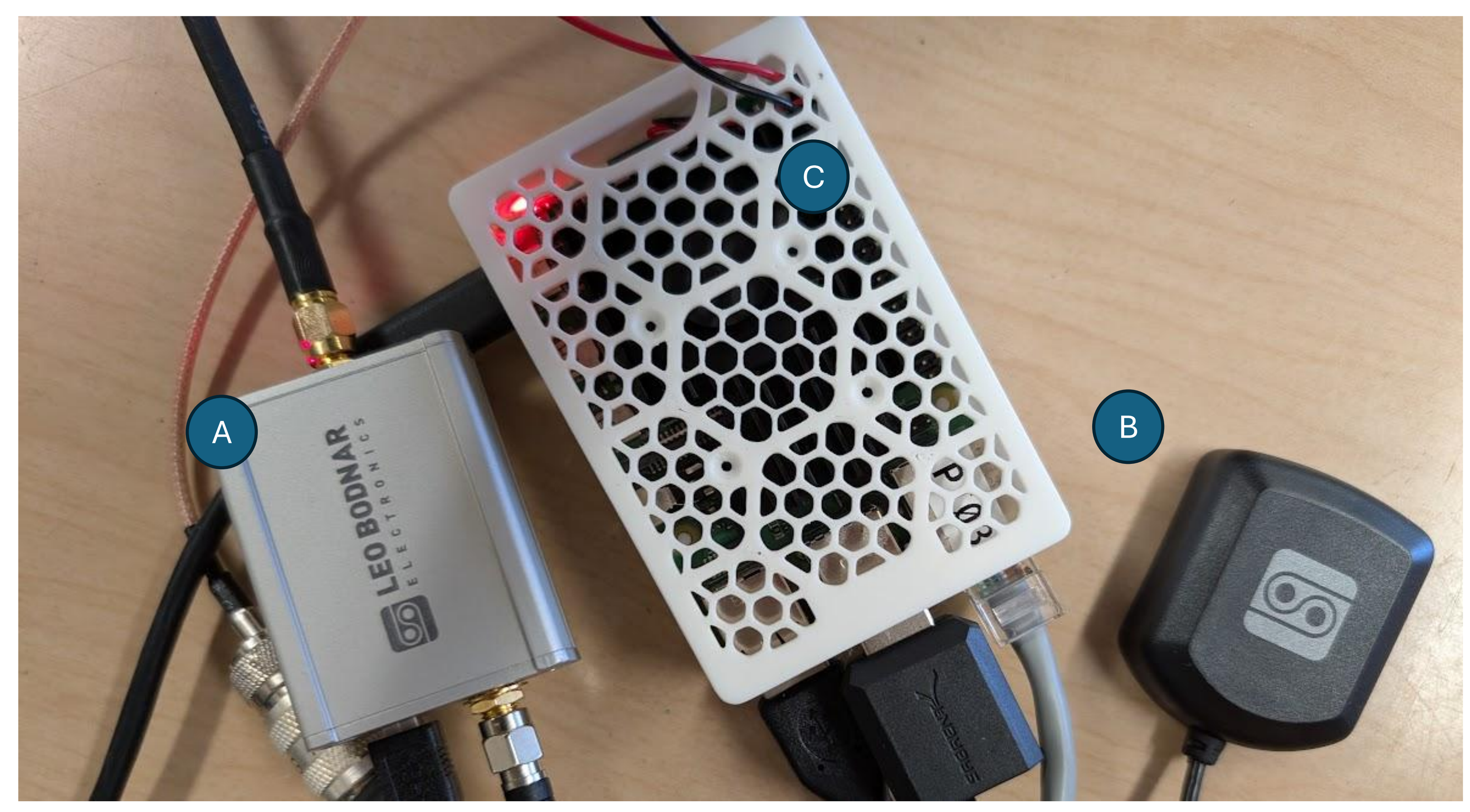

Figure 3. Grape 1 Setup. The Leo Bodnar GPSDO (A) provides a steady reference frequency at 10 MHz using a GPS antenna (B) to ensure the receiver stays on the carrier frequency. The Raspberry Pi (C) integrates the components from Figures 4 and 5 and uploads the data to the HamSCI database.

Figure 4. HF Antenna. The Amateur Radio Club's 40m and 10m dipole (A) sits about 55 feet above ground level and connects directly to the mixer board (Figure 5).

Experimental Results: Doppler Shift and Space Weather Visualization

To visualize the variations in the ionosphere, the Raspberry Pi plotted daily received data (1 data point per second). For days without space weather activity, the daily plots of Doppler shift and gain would follow average trends (Figure 7). On days with large geomagnetic disturbances or solar flares, the Doppler shift would greatly vary when compared to normal behavior (Figure 8).

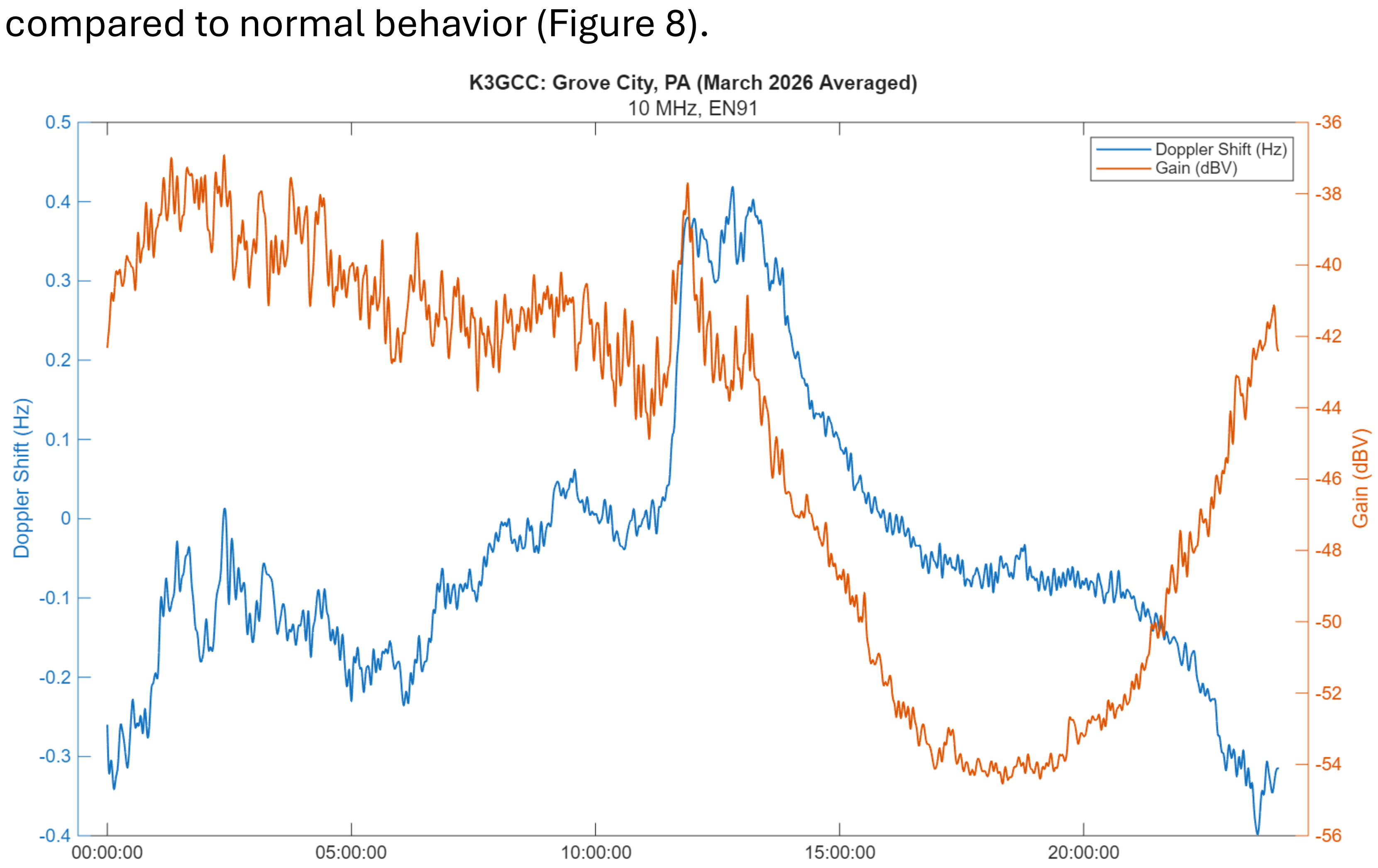

Figure 7. Average Doppler Shift and Power Trends

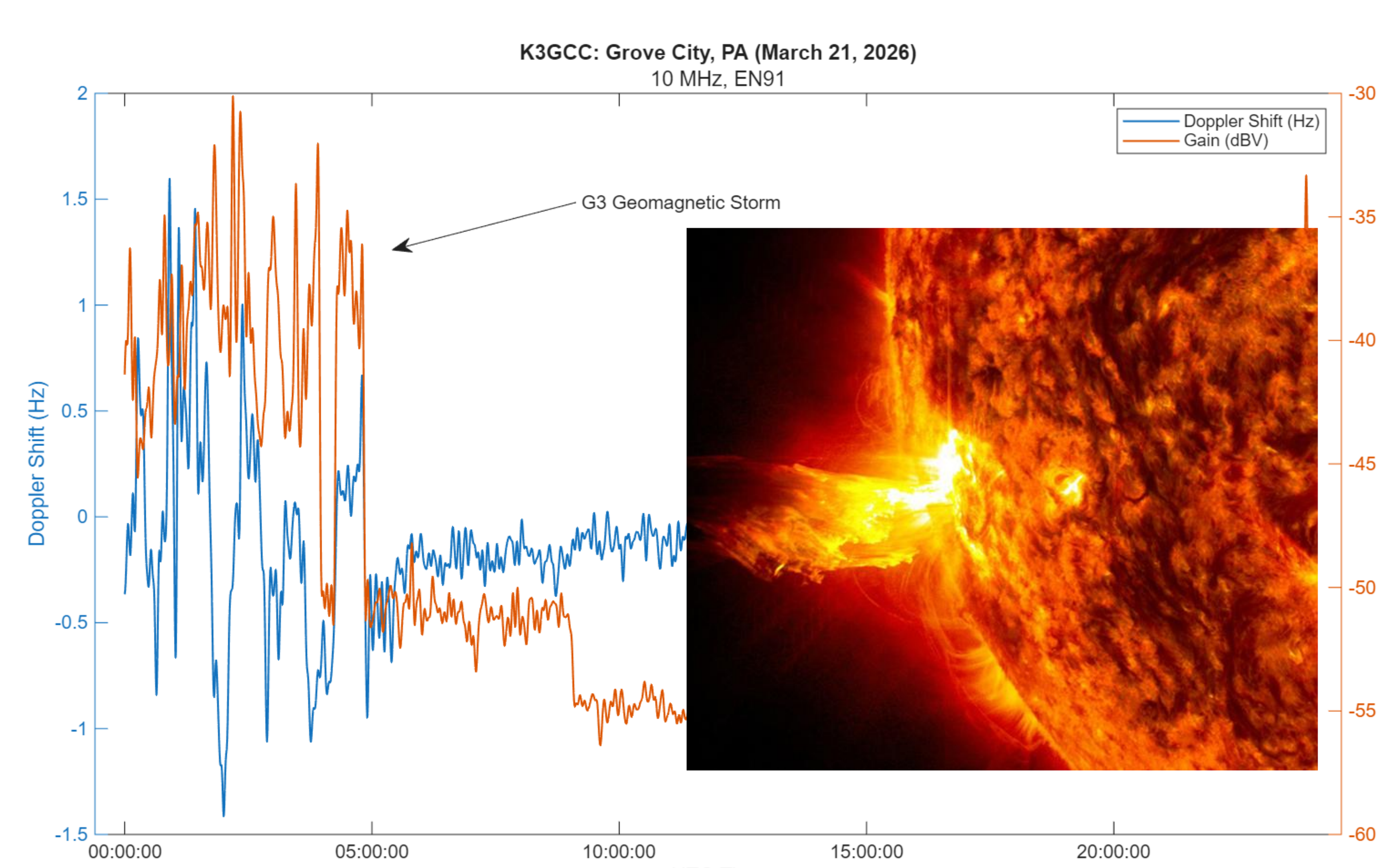

Figure 8. G3 Level Geomagnetic Storm Visualization
Solar flare image: NASA

Next Steps: Continuing Space Weather Research

- **Calculate the velocity of ionosphere**
  - The doppler shift uses this equation:

$$f_0 = f_s\left(\frac{v}{v \pm v_s}\right)$$

- **Develop a storm's G-Level metric**
  - Find a key indicator of geomagnetic storms
- **Node Correlation**
  - Continue to aggregate data from other nodes and compare results to our data
- **Examine literature on space weather**
  - Compare papers and analyses on space weather phenomenon
  - Compare our data to replicate or analyze results from other paper's data