

A Low-Cost Low-Power Chirp Ionosonde for Studying the Ionospheric Impacts of Space Weather

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Introduction

The ionosphere is a region of the atmosphere characterized by both ions and electrons. It is highly active and experiences changes in parameters such as electron density at different altitudes, based on the energy absorbed from the sun. Ionosondes are a type of radar used to gather data about the height of the ionosphere by transmitting a signal towards the ionosphere. This signal is refracted back to the Earth's surface and received in such a manner that return echoes can be timed to calculate the height profile of the bottomside ionosphere. Traditional ionosondes require large antenna systems and high amounts of power. Recent advancements in software defined radio (SDR) technology, advanced digital signal processing, and computational efficiency enable the size, cost, and power demands of an ionosonde system to be reduced.

An Ettus N200 Universal Radio Peripheral was used during the 2024 total solar eclipse, and the system was successfully used to sound the ionosphere. Data from this event is shown in figure 1. Since then, the system has been updated. It is more compact, consumes less power, and is more reliable.

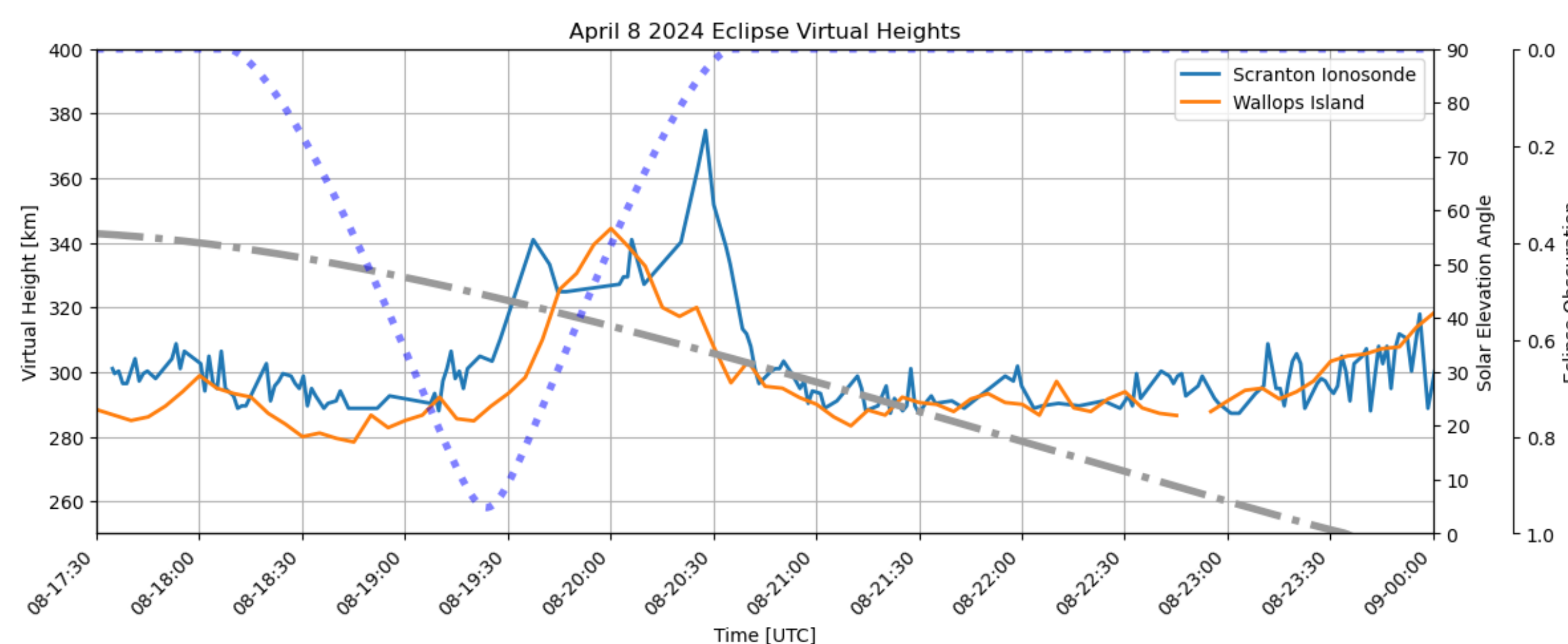


Figure 1. Virtual height data collected during the 2024 solar eclipse compared to the virtual height data collected by Wallops Island. Scranton data collected on 7.025 MHz and Wallops data averaged over 6.8-7.2 MHz

Methodology

- The system has been updated to use the Red Pitaya SDRlab 122-16. This smaller and more affordable board is able to sound the ionosphere, using the same methods as the Ettus based system.
- The system uses two amateur radio fan dipoles with one serving as a transmit antenna, and the other serving as the receiving. Using two allows recording while transmitting, simplifying our system. We can find the direct path and the echo in the same signal.

- We were granted an experimental license by the FCC enabling us to transmit between 2 MHz and 10 MHz at up to 300 Watts. Recently we have kept our transmission power below 5 W. Despite this, we are sounding the ionosphere on the 3.5 MHz and 7 MHz bands.
- A Shackmaster power supply is used for its compact size and ability to be control through software.
- No major amplifiers are used allowing the footprint of the system to be reduce significantly. Most of the components used are mounted to a wood board enabling more portability.
- An Elecraft wattmeter has been placed in line with the antenna to monitor power output and SWR remotely.

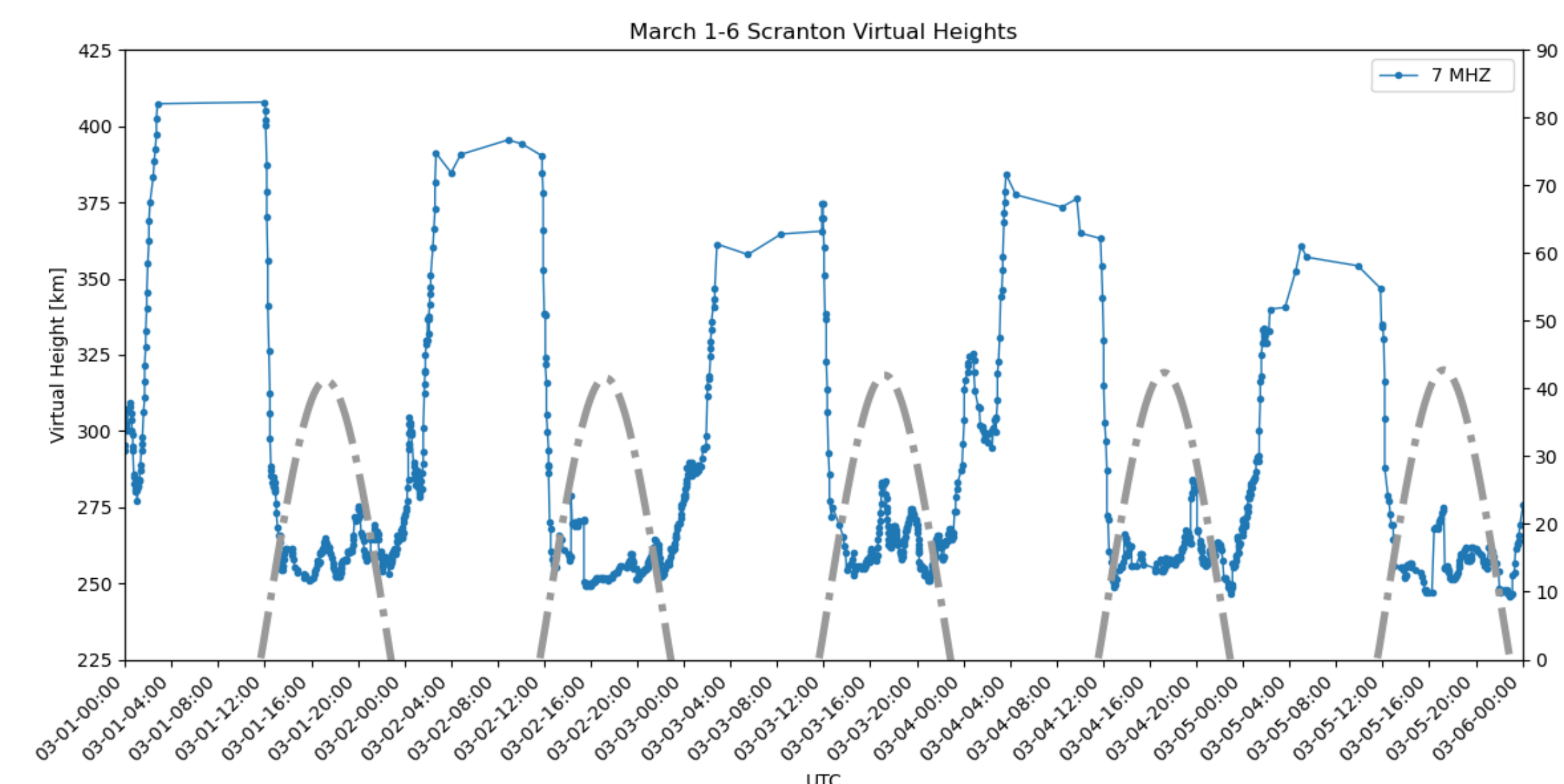


Figure 2. Five days work of virtual height data from 7 MHz on our ionosonde. The measured virtual height follow the day-night cycle

Data and Analysis

- Due to our limited output power, we have relied on cross correlation to measure the delay. By cross correlating the recorded signal, we are able to find the time delay between the direct path and the return echo.
- The data recorded on our system closely follows the day-night cycle as seen in figure 2.
- The virtual layer heights measured align closely to GIRO data from both Millstone Hill and Alpena. This is displayed in Figure 3.

Conclusion

- The system is now running reliably and using very little power. The antennas currently used are less than ideal, as they limit our transmit bandwidth. We plan to change antennas as well as increase our power slight to reduce the systems vulnerability to noise
- In the last year the system has been reduced in size and cost. The system is now more reliably sounding the ionosphere on more frequencies. Remote monitoring and control has also improved significantly.
- By recording echoes on additional frequencies, we plan to gain the ability to calculate the true height

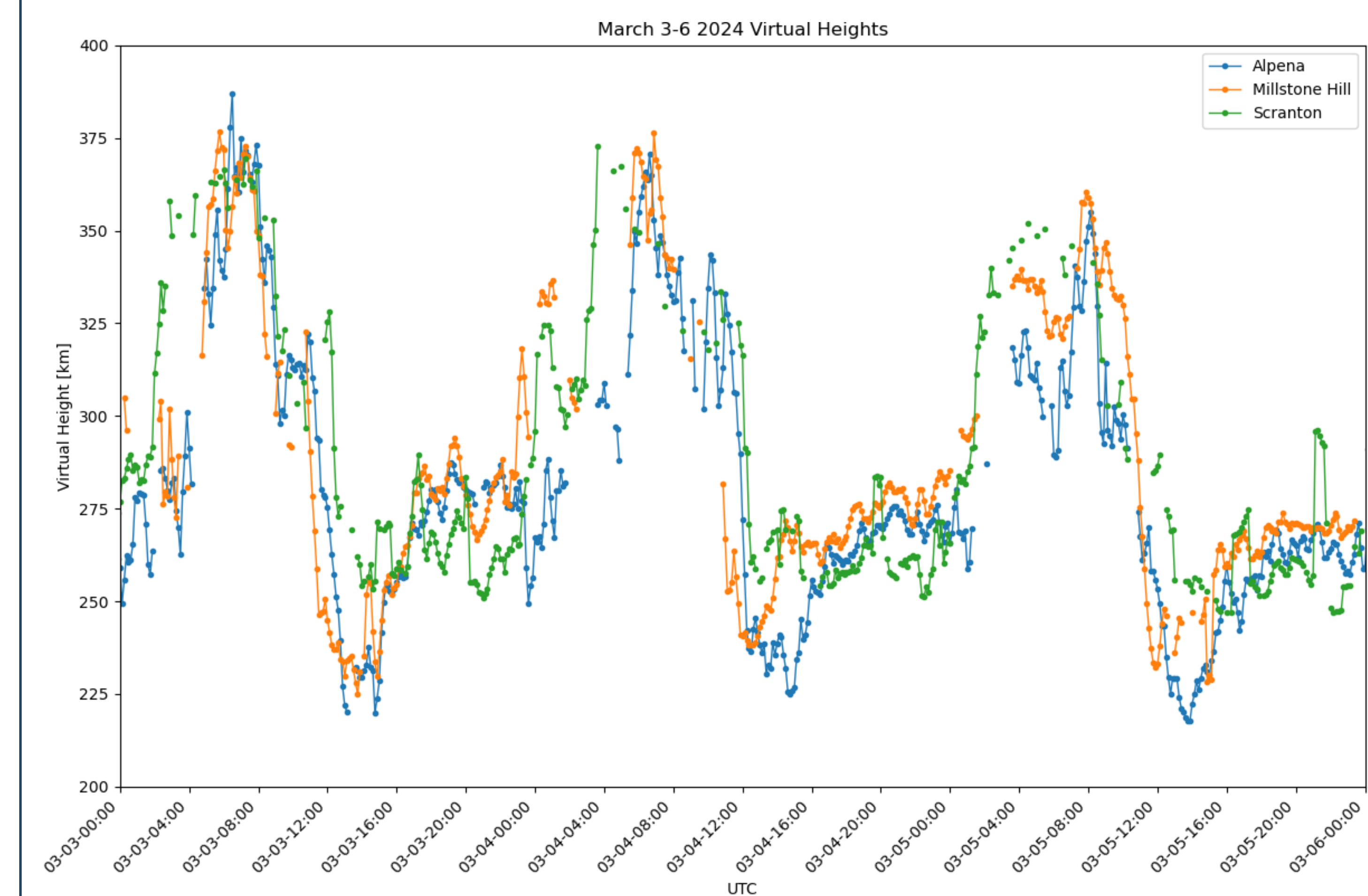


Figure 3. Plot comparing Scranton ionosonde data to minimum virtual height values from Alpena and Millstone Hill.

References

Lloyd, William C. (2019). *Ionospheric Sounding During a Total Solar Eclipse*. Master's Thesis, Virginia Tech Department of Electrical and Computer Engineering, <http://hdl.handle.net/10919/89951>.

McGwier, Robert (2018). "Using GNU Radio and Red Pitaya for Citizen Science" in *GNU Radio Conference 2018*, Las Vegas, NV, https://www.gnuradio.org/grcon/grcon18/presentations/Using_GNU_Radio_and_Red_Pitaya_for_Citizen_Science/.

Acknowledgements

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