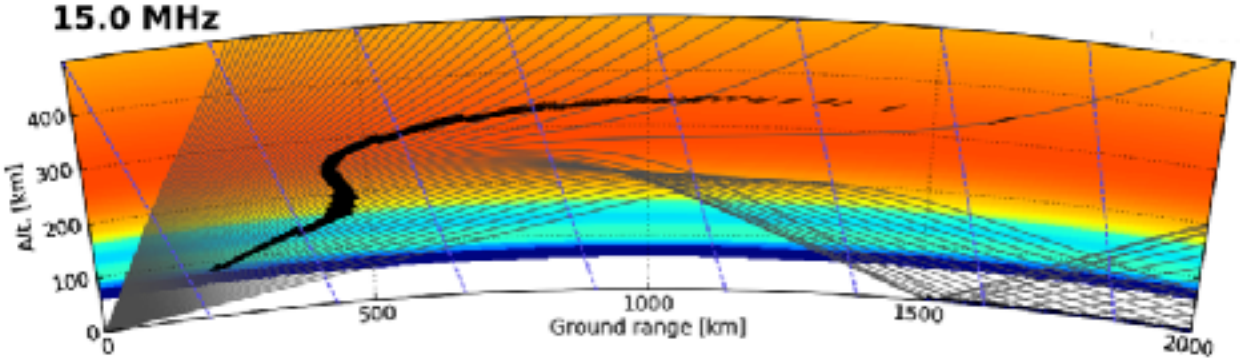
HamSCI

Ham Radio Science Citizen Investigation



Amateur Radio and Space Physics

Making the Connection

Gary Mikitin, AF8A

- Licensed since 1977 (first call, WD8MGP).
- Engineering degree from CWRU, 1984.
- 34 years, working in the arc welding industry. Retired in 2018…no regrets!
- Typically heard on CW…contesting, ragchewing, DX'ing (such as it is, with only a 20m qtr wave vertical)

Today's Talk

The What - Why - Who - How of HamSCI

- HamSCI Basis and Purpose
- Citizen scientist - volunteers
- Collegiate and community interactions
- Research Interests
- Past events
- Join our current and future research efforts
- Upcoming event: MSQP
- Getting involved

Ham Radio Science Citizen Investigation

HamSCI Booth at the 2023 Dayton Hamvention

Founder/Lead HamSCI Organizer:
Dr. Nathaniel A. Frissell, W2NAF
The University of Scranton

A collective that allows university researchers to collaborate with the amateur radio community in scientific investigations.

Objectives:

1. **Advance** scientific research and understanding through amateur radio activities.
2. **Encourage** the development of new technologies to support this research.
3. **Provide** educational opportunities for the amateur radio community and the general public.

Today's Talk

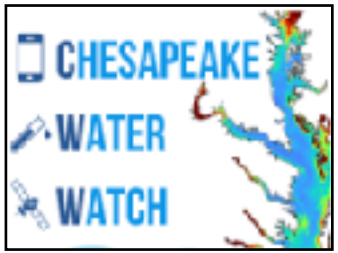
The What - Why - Who - How of HamSCI

- HamSCI Basis and Purpose
- Volunteers, aka citizen scientists
- Collegiate and community interactions
- Research Interests
- Past events
- Join our current and future research efforts
- Upcoming event: MSQP
- Getting involved

Citizen Science

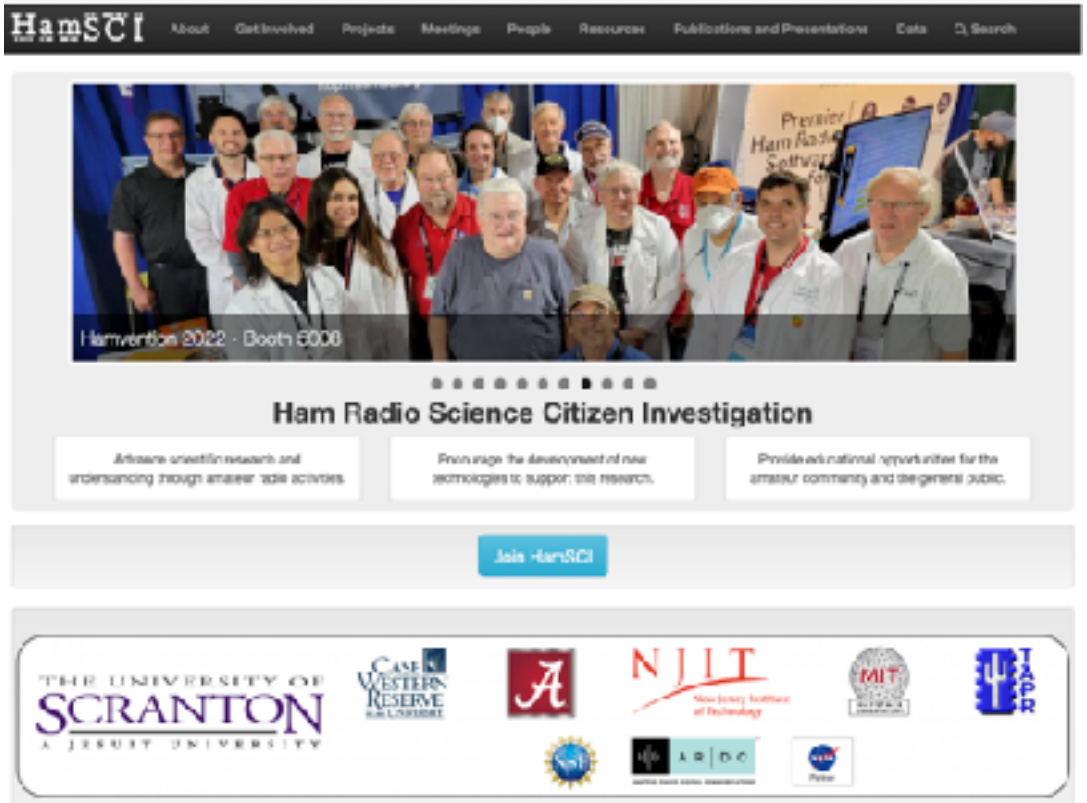
"Scientific work, for example collecting information, that is done by ordinary people without special qualifications, in order to help the work of scientists."

NASA-supported projects involving citizen scientists:



science.nasa.gov/citizen-science/

HamSCI's Research and Citizen Science Focus



hamsci.org

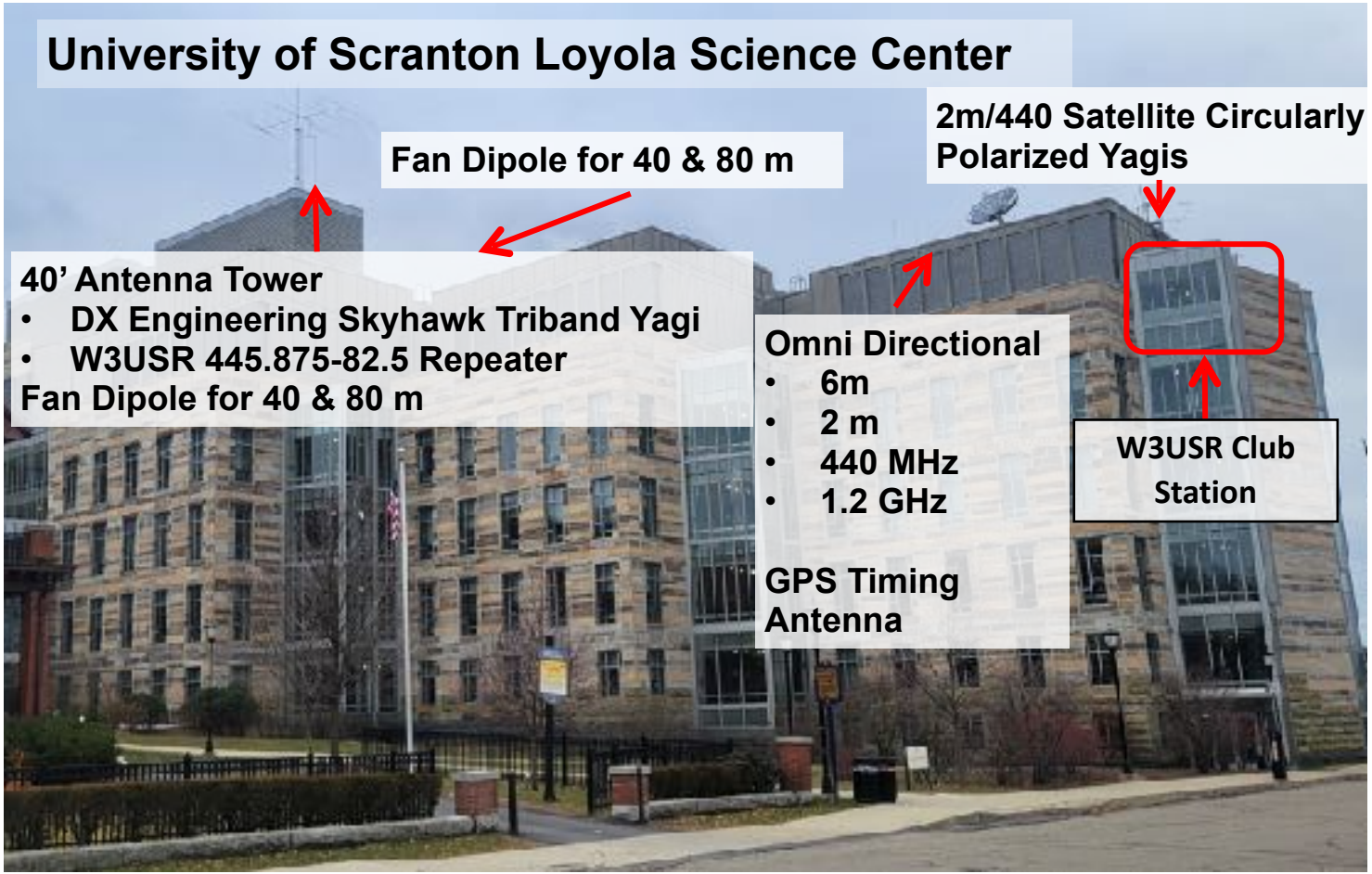
Today's Talk

The What - Why - Who - How of HamSCI

- HamSCI Basis and Purpose
- Citizen scientist - volunteers
- Collegiate and community interactions
- Research Interests
- Past events
- Join our current and future research efforts
- Upcoming event: MSQP
- Getting Involved

University of Scranton (PA) Loyola Science Center

University of Scranton Loyola Science Center



W3USR Weekly Open House

Ham Gear

- HF
  - Icom IC-7610
  - Icom IC-7300
  - Acom 1010 Amplifier
- VHF/UHF/Satellite
  - Icom IC-9700
  - Yaesu FT-400D
- 445.875 - 82.5 W3USR Repeater

Funding & Donations

- $196,241 Grant from ARDC
- $20,000 Private Donations
- NSF, DX Engineering, and WN3A

Construction

- Professionally Designed and Installed by Broadcast Sciences, LLC (Jeff DePolo WN3A)

Active HamSCI Collegiate Stations

K2MFF

W8EDU

W3USR

Today's Talk

The What - Why - Who - How of HamSCI

- HamSCI Basis and Purpose
- Citizen scientist - volunteers
- Collegiate and community interactions
- Research Interests
- Past events
- Join our current and future research efforts
- Upcoming event: MSQP
- Getting involved

The Ionosphere

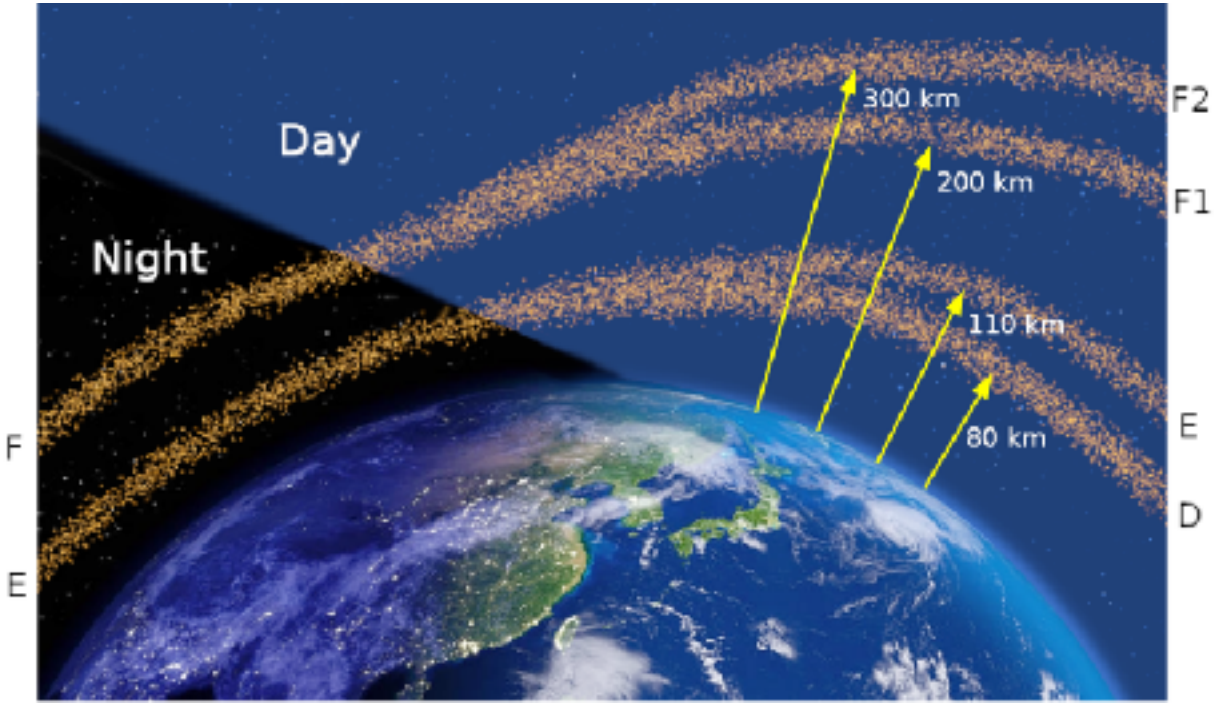


Figure by Carlos Molina (commons.wikimedia.org)

The Ionosphere: An Common Area of Interest

The ionosphere is a prime area of interest for HamSCI. It is a prime area of interest for hams. The trick is to combine efforts so that everyone benefits.

Hams can contribute to HamSCI in many different ways:

- Assisting with new equipment design, test, debugging
- Hosting scientific instruments, generating research-worthy data (PSWS)
- Using or acquiring skills related to data analysis, authoring general interest articles and/or technical papers for science publications and conferences
- Joining HamSCI meetings and telecons - opportunites for learning
- Participating in events on the ham bands, such as contests and operating challenges. These events can be 'just for fun' or they could be for data generation.

Today's Talk

The What - Why - Who - How of HamSCI

- HamSCI Basis and Purpose
- Citizen scientist - volunteers
- Collegiate and community interactions
- Research Interests
- Past events & accomplishments
- Join our current and future research efforts
- Upcoming event: MSQP
- Getting involved

HamSCI Eclipse Operating Events - 2017, 2023, 2024

HamSCI sponsored two very different operating events during the past eclipses

- **Solar Eclipse QSO Party:** A fairly typical low band contest, for CW, SSB and FT8
- **Gladstone Signal Spotting Challenge:** A unique event, a contest of sorts, but for one-way transmissions (using digital modes WSPR and FST4W, from the WSJT software package)
- **Combined, the logs from the most recent events created over 760,000 data points (Oct, 2023 eclipse), and over 1.1 million data points (Apr, 2024 eclipse)**

GRAPE & WSPRDaemon HF GRAPE Doppler Receivers

Developed as the "GRAPE" Receiver led by John Gibbons N8OBJ, Case Western Reserve University / Case Amateur Radio Club W8EDU.

Primary objective is to measure Doppler Shift of HF standards stations like WWV & CHU. (GRAPE = Great Radio Amateur Propagation Experiment)

GRAPE v1
- Single Frequency
- Build it yourself
- hamsci.org/grape1

GRAPE v2
- 3 Simultaneous Frequency Bands
- Preassembled
- 30 Deployed for Total Eclipse

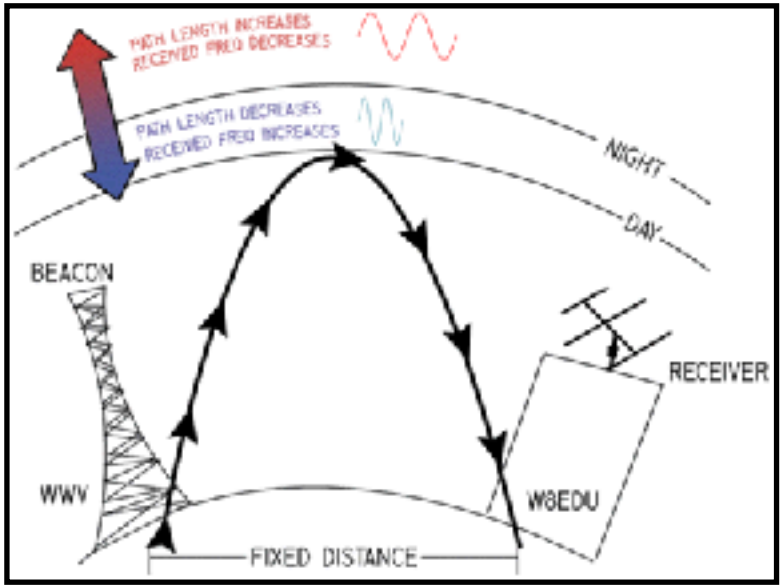
WSPRDaemon-GRAPE
- Uses RX-888 HF SDR, KA9Q-Radio & WSPRDaemon Software
- 9 (or more!) simultaneous HF Doppler bands
- Decodes WSPR/FST4W spots, too!

GRAPE PSWS - Doppler Shift Measurements

A full explanation of the science behind the Grape PSWS is beyond the scope of this talk.

In the simplest of terms, we can sense the bottomside of the ionosphere by measuring the received frequency of stations such as WWV to milliHertz precision.

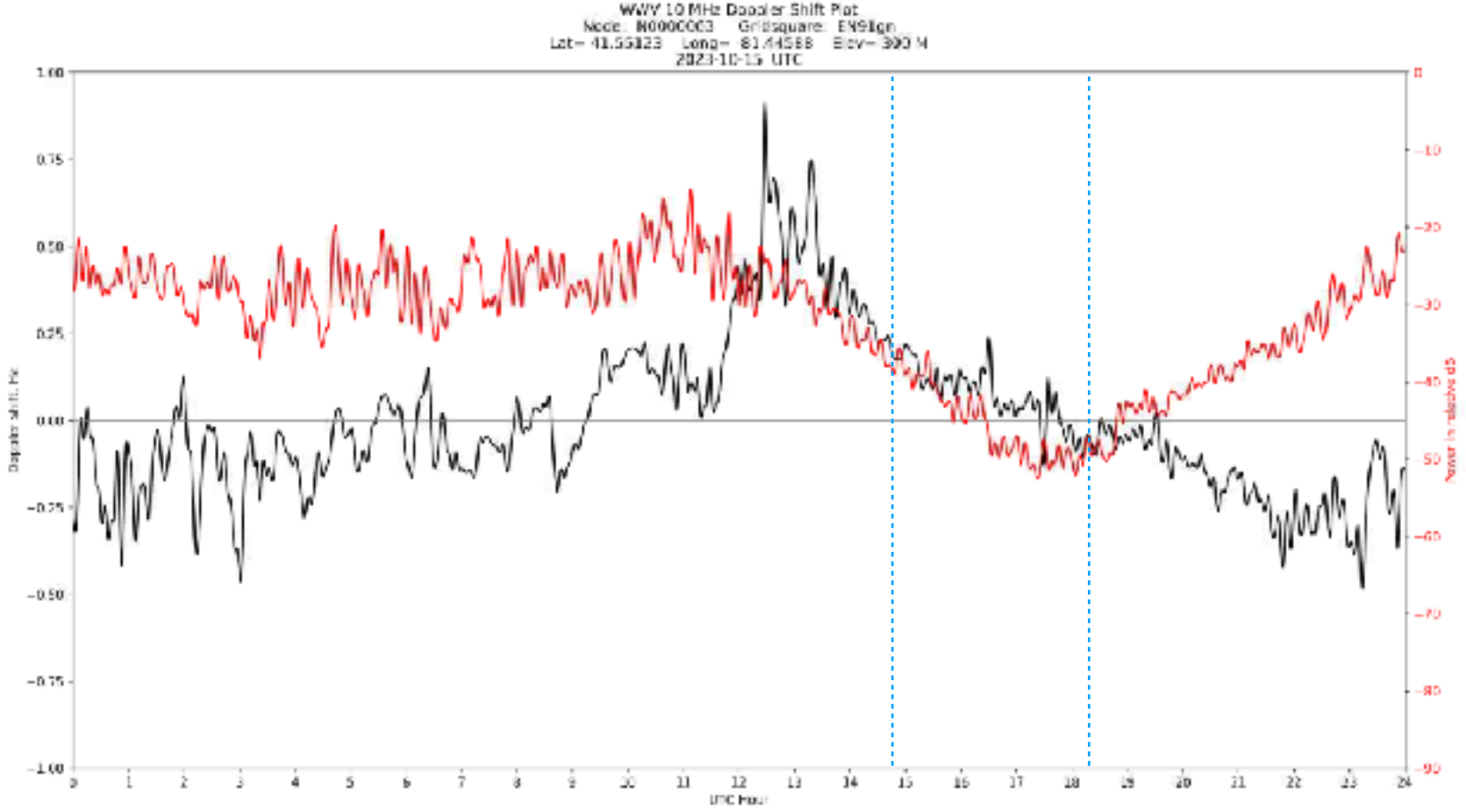
Grape hosts can easily see ionospheric changes in their stations data.



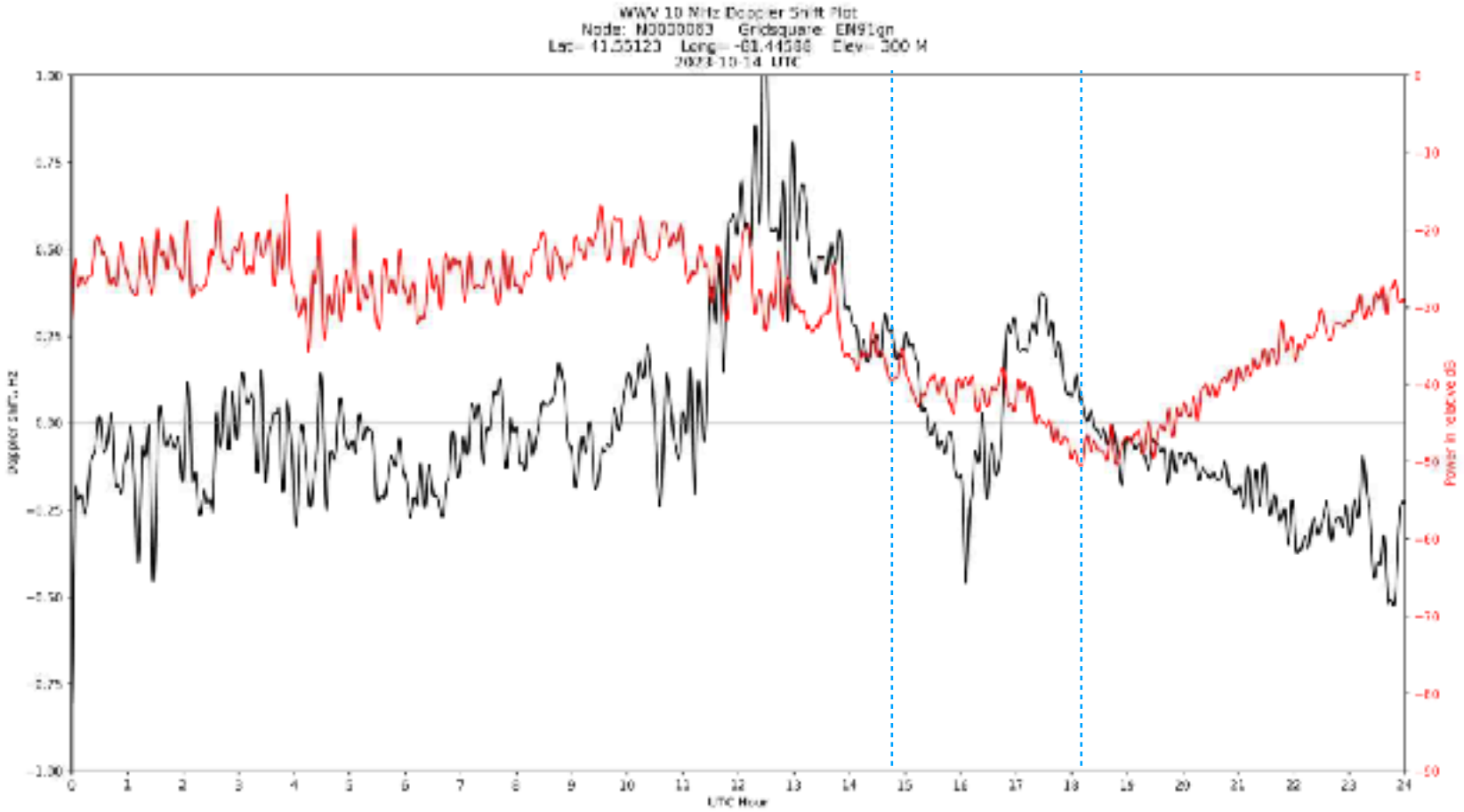
Full details on how to build, how to participate and the science behind the PSWS, visit hamsci.org/grape

Image: C. Collins, KD8OXT

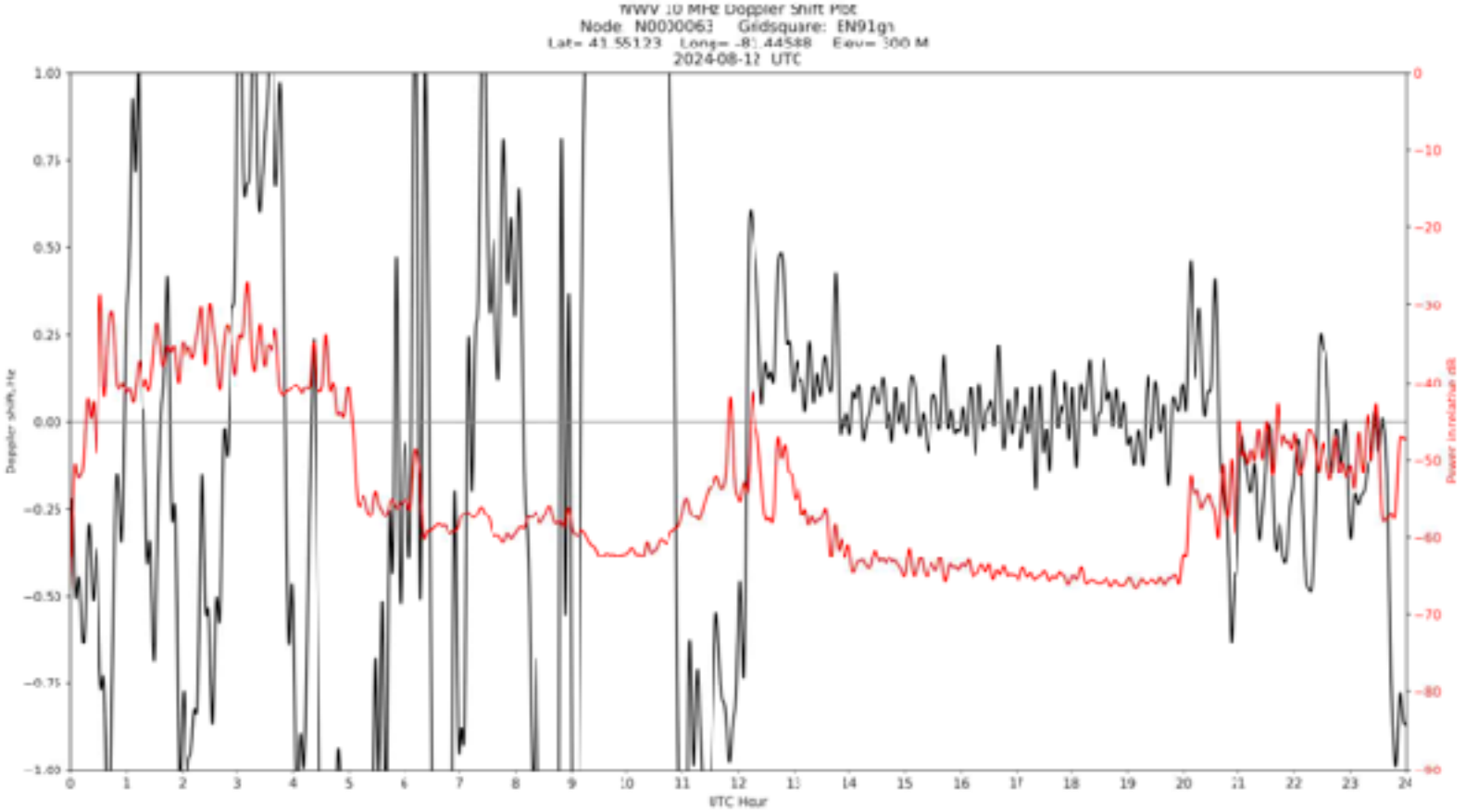
Grape 1 Doppler Plot - Quiet Solar Conditions



Grape 1 Doppler Plot - Annular Eclipse Day



Grape 1 Doppler Plot - Geomagnetic Storm



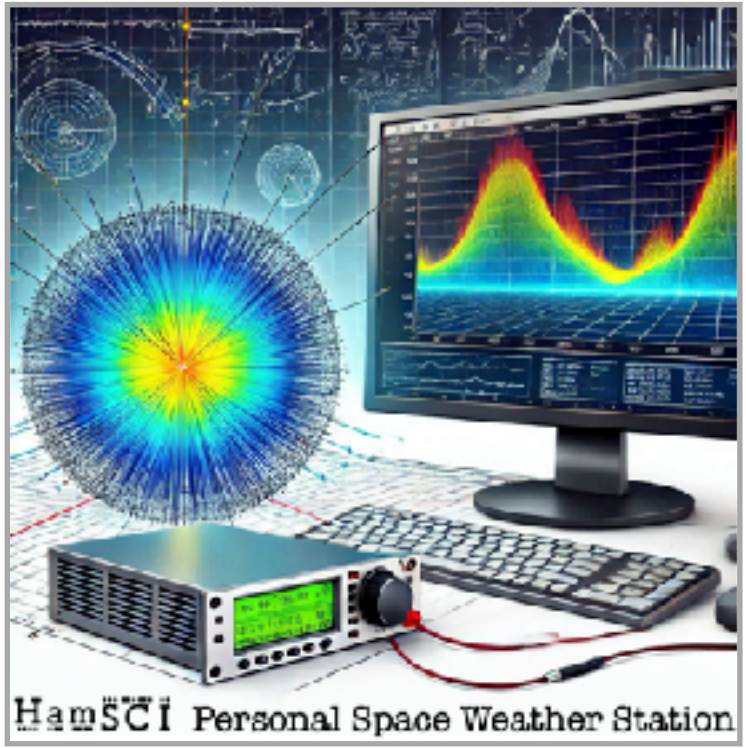
Today's Talk

The What - Why - Who - How of HamSCI

- HamSCI Basis and Purpose
- Citizen scientist - volunteers
- Collegiate and community interactions
- Research Interests
- Past events & accomplishments
- Join our current and future research efforts
- Upcoming event: MSQP
- Getting involved

HamSCI PSWS Network: Call for Hosts

The HamSCI Personal Space Weather Station (PSWS) Network is a Distributed Array of Small Instruments (DASI*)

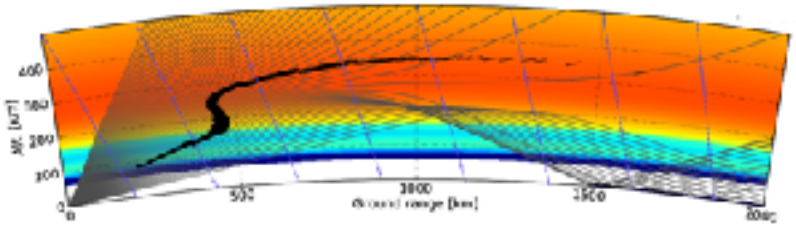


*NSF Funding Program 24-538 announced February 9, 2024

HamSCI PSWS Network: What and Why

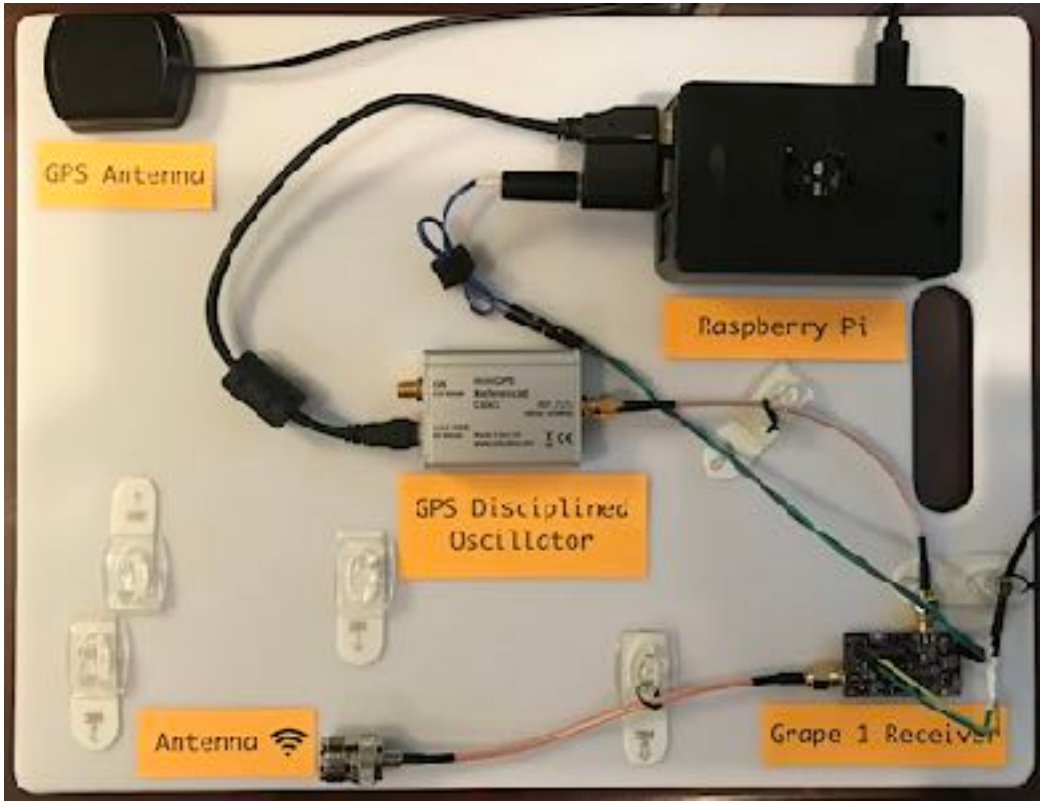
What it is: An interconnected system of instruments, making frequent measurements across a wide geographic area

Why build it: The network will help in understanding the local, regional, and global scale processes that are essential for addressing fundamental questions in solar and space physics.



History Lesson: HamSCI's GRAPE Network

HamSCI, thorugh its volunteers and participating institutions, designed and deployed the GRAPE* series of instruments prior to the North American solar eclipses in 2023/24.



*GRAPE = Great Radio Amateur Propagtion Experiment

HamSCI PSWS Network

Definition: An interconnected system of instruments, making frequent measurements across a wide geographic area

Goal: Determine the local, regional, and global scale processes that are essential for addressing the fundamental questions in solar and space physics - including radio wave propagation

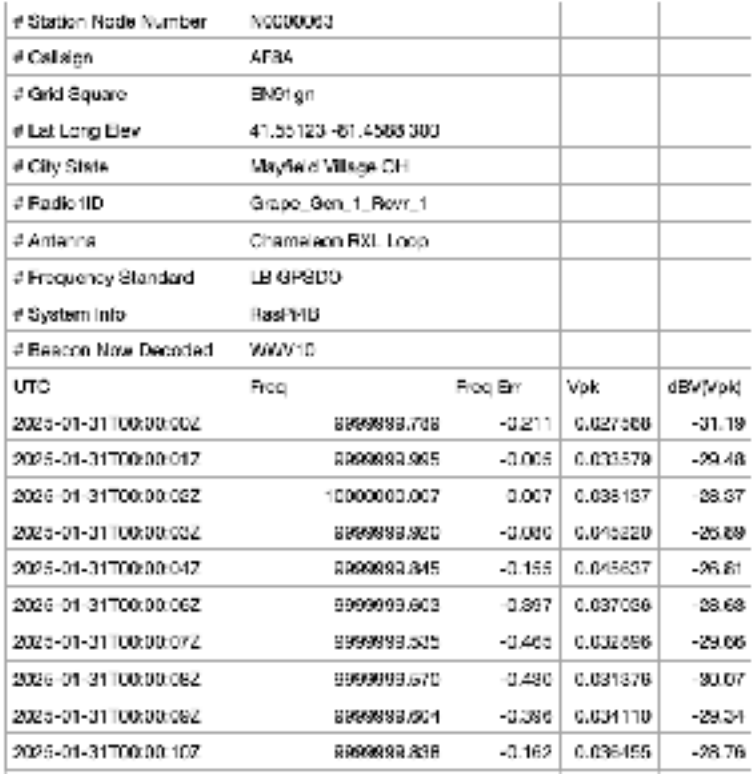
PSWS Network: Frequent Measurements

HamSCI's current GRAPE* instruments are operating 24/7/365, creating, at a minimum, one data point *per second, per instrument*

The future PSWS instruments will operate similarly - monitoring, collecting, uploading data to a central server

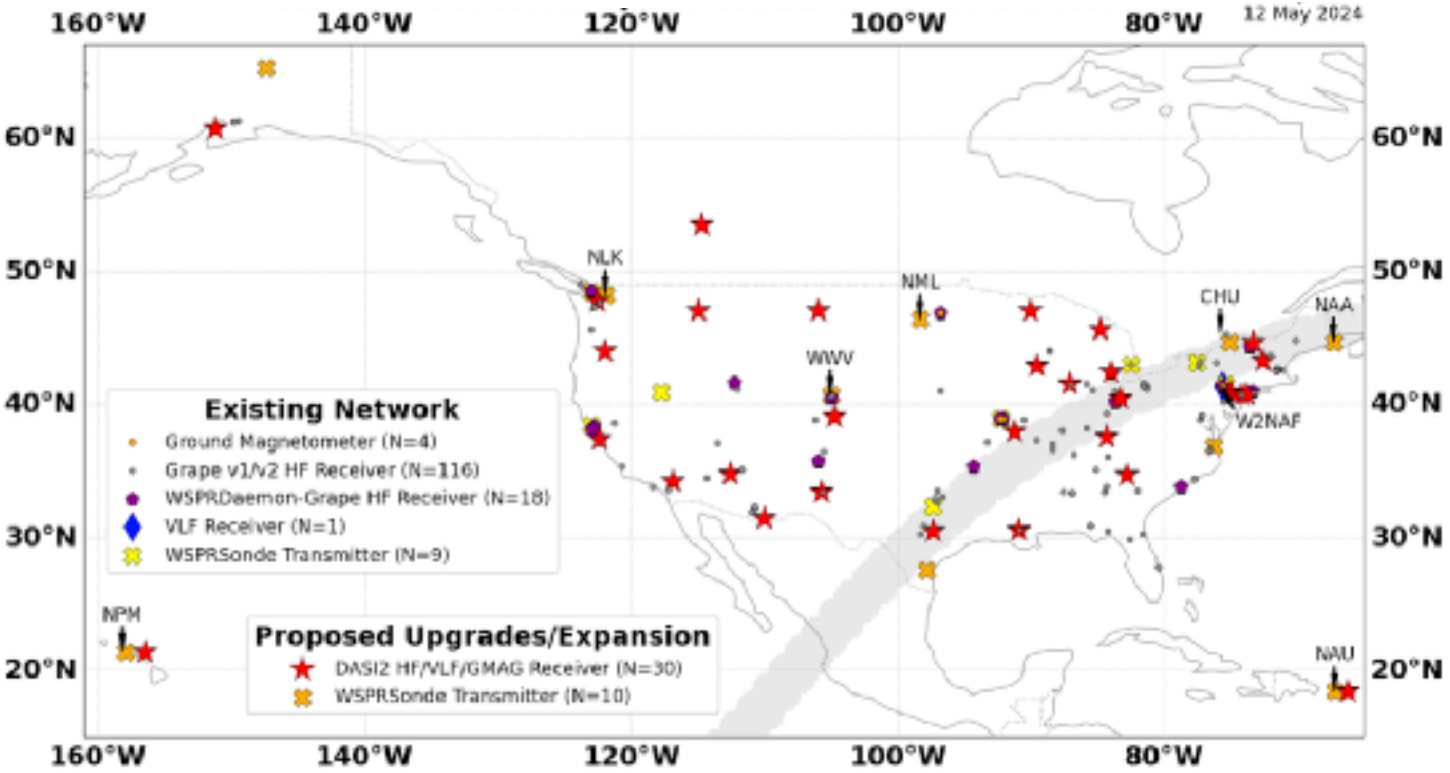
*GRAPE = Great Radio Amateur Propagation Experiment

To learn more about GRAPEs, visit hamsci.org/psws



# Station Node Number	N0000003			
# Callsign	AI3A			
# Grid Square	EN91gh			
# Lat Long Elev	41.55123 -81.4565 300			
# City State	Mayfield Village OH			
# Radio ID	Grape_Gen_1_Rcvr_1			
# Antenna	Chameleon RX Loop			
# Frequency Standard	LB GPSDO			
# System Info	RasPiID			
# Beacon Now Decoded	WWV10			
UTC	Freq	Freq Err	Vpk	dBV[vpk]
2025-01-31T00:00:002	9999999.708	-0.211	0.027369	-31.19
2025-01-31T00:00:017	9999999.995	-0.005	0.033579	-29.48
2025-01-31T00:00:032	10000000.007	0.007	0.036187	-28.87
2025-01-31T00:00:032	9999999.920	-0.080	0.018229	-25.89
2025-01-31T00:00:047	9999999.845	-0.155	0.045637	-26.81
2025-01-31T00:00:062	9999999.603	-0.397	0.037086	-28.68
2025-01-31T00:00:077	9999999.535	-0.465	0.032586	-29.66
2025-01-31T00:00:092	9999999.570	-0.430	0.031376	-30.07
2025-01-31T00:00:092	9999999.604	-0.396	0.031119	-29.91
2025-01-31T00:00:107	9999999.838	-0.162	0.036455	-28.76

PSWS Network: Wide Geographic Coverage



Expanded PSWS Network: Key Elements

Rx Hardware: Three Instruments

- Wideband HF SDR, VLF Receiving Apparatus, Ground Magnetometer

Tx Hardware

- WSPRSonde 8-band WSPR/FST4W GPS disciplined transmitter

Host Locations

- Rx: Co-Located Hardware: HF+VLF+Magnetometer
- Rx: A Suitable Electromagnetic Environment (ie RF quiet)
- Rx: Reliable Internet
- Tx: Multi-band antenna(s), 80-6 meters
- Reliable power

PSWS Network: Critical Elements

Rx Hardware: Three Instruments

- Wideband HF SDR, VLF Receiving Apparatus, Ground Magnetometer

Tx Hardware

- WSPRSonde 8-band WSPR/FST4W GPS disciplined transmitter

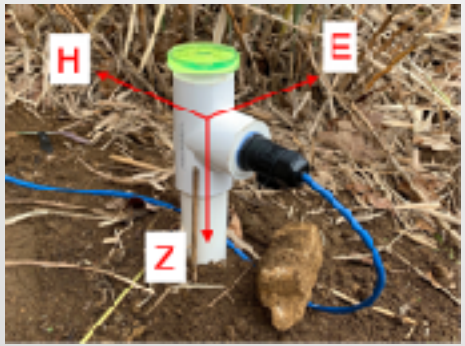
Host Locations

- Rx: Co-Located Hardware: HF+VLF+Magnetometer
- Rx: A Suitable Electromagnetic Environment (ie RF quiet)
- Rx: Reliable Internet
- Tx: Multi-band antenna(s), 80-6 meters
- Reliable power

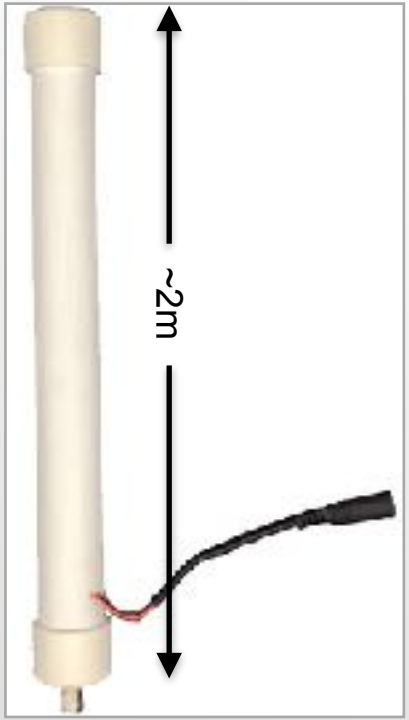
PSWS Network: Rx Hardware

WSPRDaemon Grape
Based on RX888 SDR

Active HF Antenna



Ground Magnetometer



Active VLF Antenna
+ VLF rx equipment

Images for discussion purposes only - not to scale - actual hardware may be quite different!

PSWS Network: Critical Elements

Rx Hardware: Three Instruments
- Wideband HF SDR, VLF Receiving Apparatus, Ground Magnetometer

Tx Hardware
- WSPRSonde 8-band WSPR/FST4W GPS disciplined transmitter

Host Locations
- Rx: Co-Located Hardware: HF+VLF+Magnetometer
- Rx: A Suitable Electromagnetic Environment
- Rx: Reliable Internet
- Tx: Multi-band antenna(s), 80-6 meters
- Reliable power

Rx Site Selection Challenge

Herein lies the challenge, finding sites which are…

…'RF Quiet' - on the HF bands. This means minimal noise sources (EMI, powerful local transmitters, mixing products)

…'open field' sites for the VLF antenna - with significant separtion from sources of mains harmonics

…able to bury a ground magnetometer, location free from electromagnetic influences (current carrying conductors, vehicles, etc.)

Intellectual Merit

This project will establish the only wide-spread, coordinated HF, VLF, and ground magnetometer measurements distributed primarily across the midlatitude region.

Once deployed, this enhanced PSWS network will enable researchers to investigate both local and continental space effects, including those caused by traveling ionospheric geomagnetic storms.

Continued support of the network will enable the ongoing collection of a dataset spanning the peak years of Solar Cycle 25, and support future studies of long-term climatology.

Intellectual Merit

This project will establish the only wide-spread, coordinated HF, VLF, and ground magnetometer measurements distributed primarily across the midlatitude region.

Once deployed, this enhanced PSWS network will enable researchers to investigate local, regional and continental space weather effects, including those caused by traveling ionospheric geomagnetic storms.

Continued support of the network will enable the ongoing collection of a dataset spanning the peak years of Solar Cycle 25, and support future studies of long-term climatology.

Intellectual Merit

This project will establish the only wide-spread, coordinated HF, VLF, and ground magnetometer measurements distributed primarily across the midlatitude region.

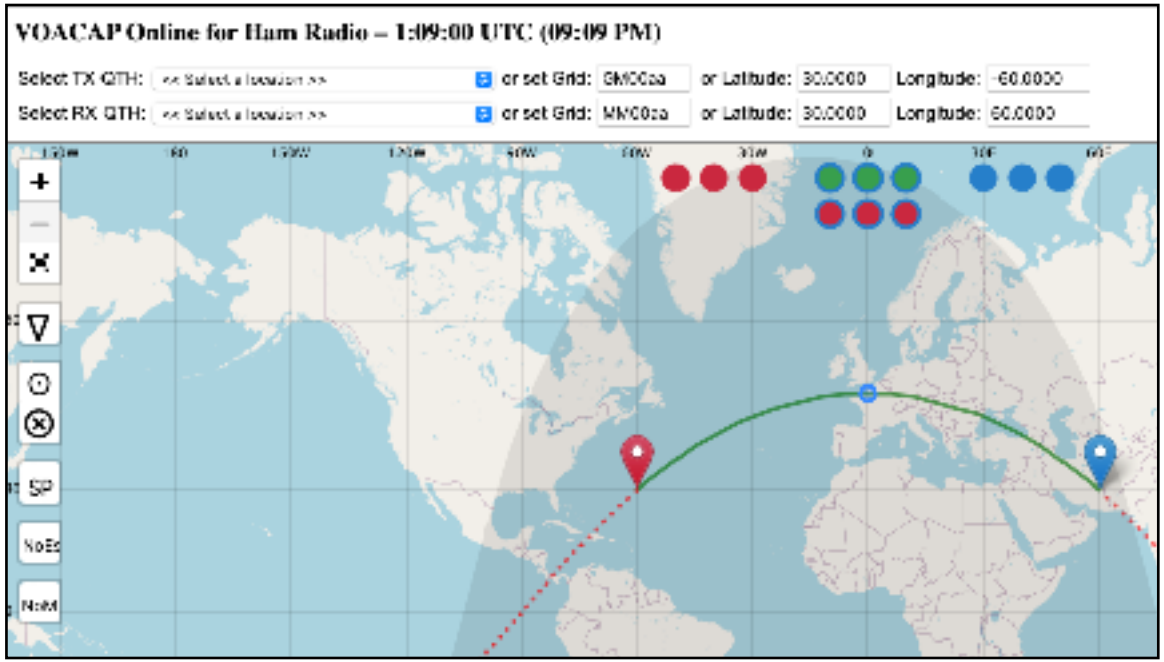
Once deployed, this enhanced PSWS network will enable researchers to investigate both local and continental space effects, including those caused by traveling ionospheric geomagnetic storms.

Continued support of the network will enable the ongoing collection of a dataset spanning the peak years of Solar Cycle 25, and support future studies of long-term climatology.

What's in it for Hams

What's in it for hams? Long term benefits of participation:

- Improved understanding of HF propagation
- Improved models of the ionosphere leading to more accurate propagation forecasts
- Satisfaction from contributing to science!



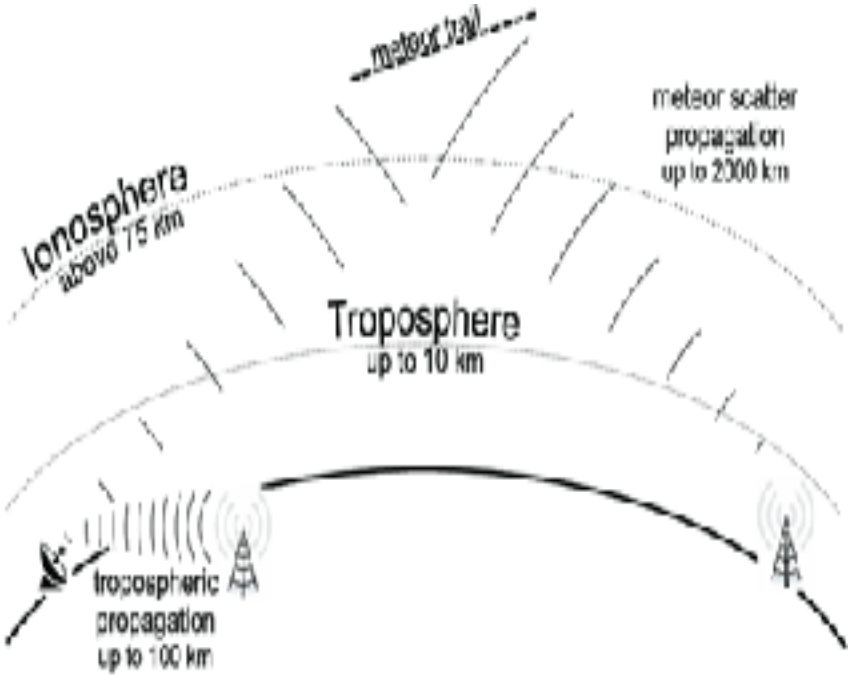
Today's Talk

The What - Why - Who - How of HamSCI

- HamSCI Basis and Purpose
- Citizen scientist - volunteers
- Collegiate and community interactions
- Research Interests
- Past events
- Join our current and future research efforts
- Upcoming event: MSQP
- Getting involved

Introduction to Meteor Scatter

- Definition: Radio signals reflected by ionized meteor trails in the atmosphere.
- Why HF? Underexplored compared to VHF; potential for novel data on:
  - Geographic reach of reflections.
  - Persistence of ionization (seconds to minutes).
  - Multi-layer interactions (E and F layers).
- **Science Motivation:** Enhance propagation models for space weather forecasting.



Meteor *Scatter QSO Party 2025*

August 11–12 & December 12–13, 2025

HamSCI

Key Dates & Meteor Showers

Perseids:

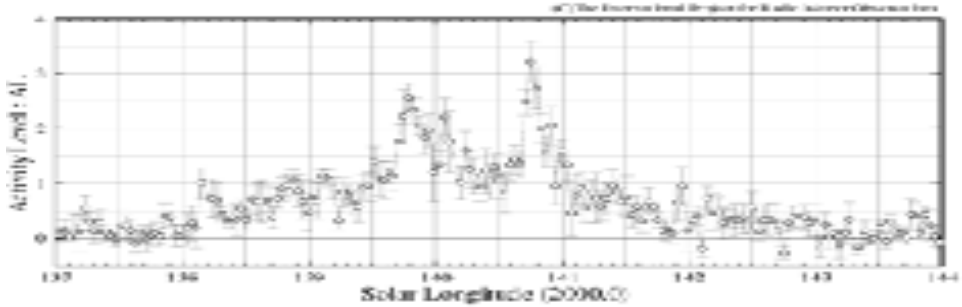
- Dates: 0000 UTC Aug 11 – 2400 UTC Aug 12, 2025.
- Peak ZHR: ~100 meteors/hour (pre-dawn optimal).

Geminids:

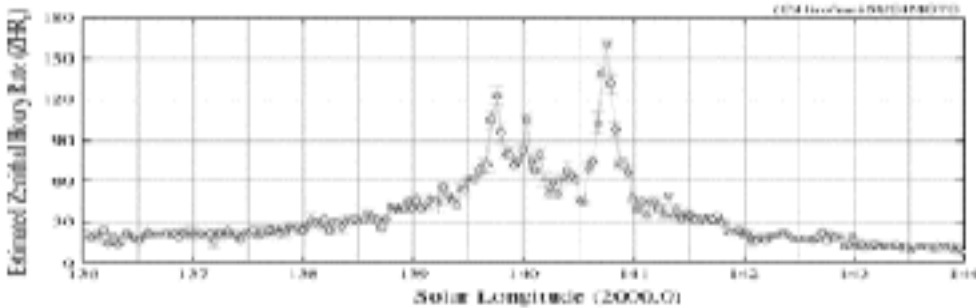
- Dates: 0000 UTC Dec 12 – 2400 UTC Dec 13, 2025.
- Peak ZHR: ~120 meteors/hour.

Why 48 Hours?

- Capture global "early morning" peaks across time zones.
- Local pre-dawn (0400–0600 hours).
- Peak meteor showers (100–120 meteors/hour).



Activity Level Index (AL) from worldwide radio meteor observations during the Perseids 2024 meteor



Estimated Zenithal Hourly Rate (ZHRr) from worldwide radio meteor observations during the Perseids 2024 meteor shower. The graph highlights the intensity of meteor activity.

Pro Tip: "Set your alarm – the early ham gets the ping!"

Meteor *Scatter QSO Party 2025*

August 11–12 & December 12–13, 2025

HamSCI

Technical Requirements

Bands & Frequencies:

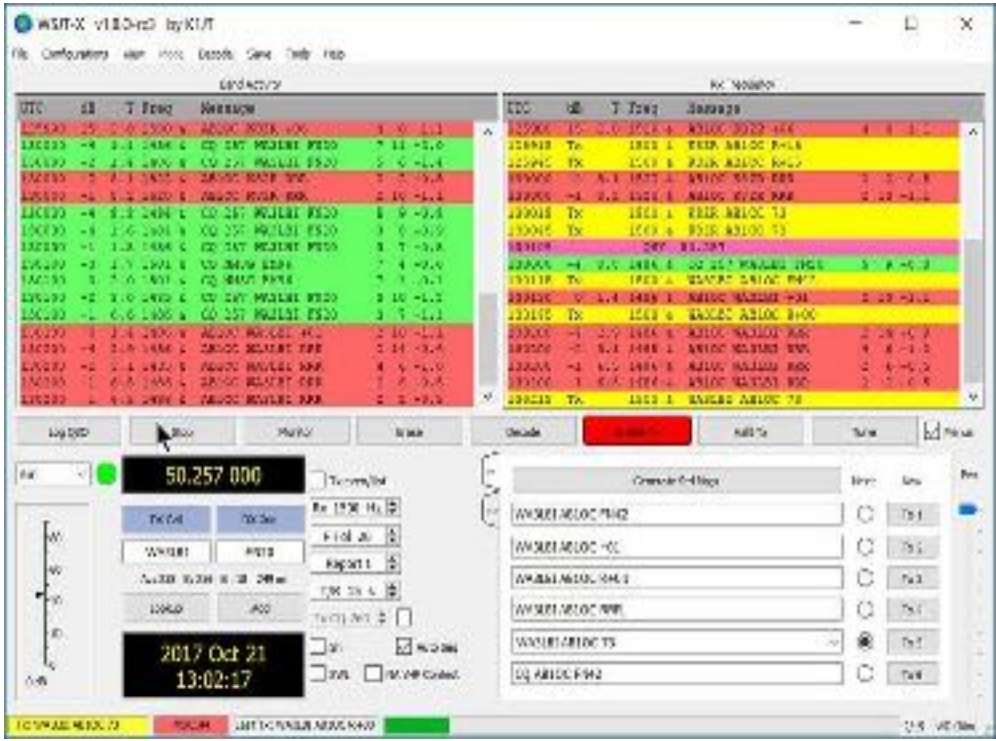
- 10m: 28.145 MHz (USB) – *Primary focus*.
- 6m: 50.280 MHz – *VHF baseline comparison*.

Mode: MSK144 – Configured for:

- 72ms bursts, Fast/Deep decode, Rx 1500 Hz, F Tol 100–200 Hz.

Software:

- WSJT-X v2.6+ (logging timestamps, SNR, grid squares).
- Send your reception repots to PSK Reporter in real time! (That's a configuration setting in WSJT-X)
- Operating is very similar to FT8



WSJT-X in MSK144 Mode on 6m Band with Real-Time Meteor Scatter Decodes

Today's Talk

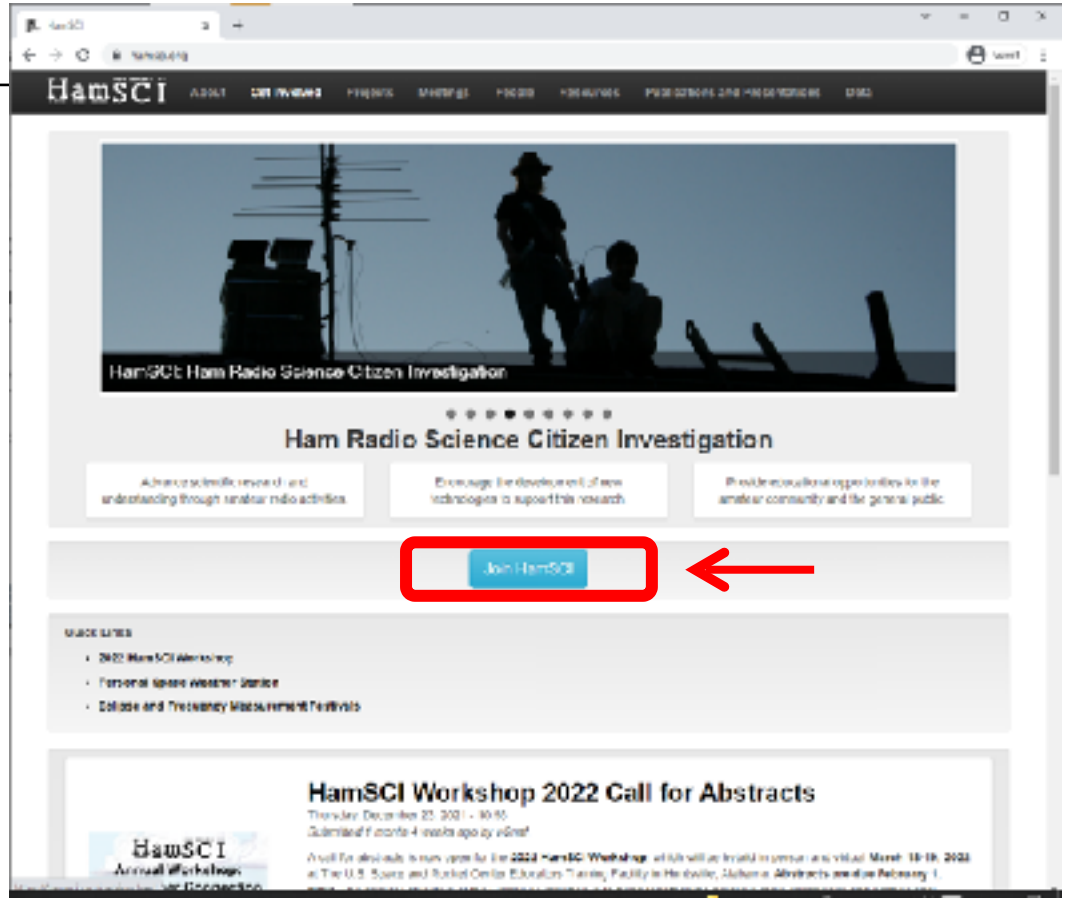
The What - Why - Who - How of HamSCI

- HamSCI Basis and Purpose
- Citizen scientist - volunteers
- Collegiate and community interactions
- Research Interests
- Past events
- Join our current and future research efforts
- Upcoming event: MSQP
- Getting involved

Getting Involved

- **HamSCI now has over 1400 members!**
- Join by visiting hamsci.org
- Our main **Google Group** is open discussion for all things related to HamSCI.
- Many specialized email lists!

hamsci.org



HamSCI Zoom Telecons - Join Us

TAPR/Tech Telecon	**Engineering telecon to support the development of high performance sensing systems, such as the WSPR Daemon/GRAPE RX-888**	**Mondays at 9 PM Eastern (Tuesdays 0100z during EST)**
PSWS Telecon 	**Telecon to support engineering and science related to the Personal Space Weather Station.**	**Thursdays at 10 AM Eastern (1400z during EST)**
HamScience Telecon	**Telecon to discuss science questions, observations and findings releated to HamSCI's research interests.**	**Thursdays at 4 PM Eastern (2000z during EST)**

Zoom links and calendar at hamsci.org/get-involved

Publications

HamSCI research has been presented and published in many different forums, from general interest magazines to peer-reviewed papers, conferences, workshops, websites and PhD dissertations. Examples include:

- American Geophysical Union Publications:
  - Space Weather
  - Geophysical Research Letters
  - Journal of Geophysical Research: Space Physics
- Frontiers in Astronomy and Space Sciences
- Institute of Electrical and Electronic Engineers' Geoscience and Remote Sensing Letters
- Institute of Electrical and Electronic Engineers' Transacations on Antennas and Propagation
- CQ, Amateur Radio Communications & Technology (CQ Communications, Inc.)
- QEX, A Forum for Communications Experimenters (American Radio Relay League)
- QST (American Radio Relay League)

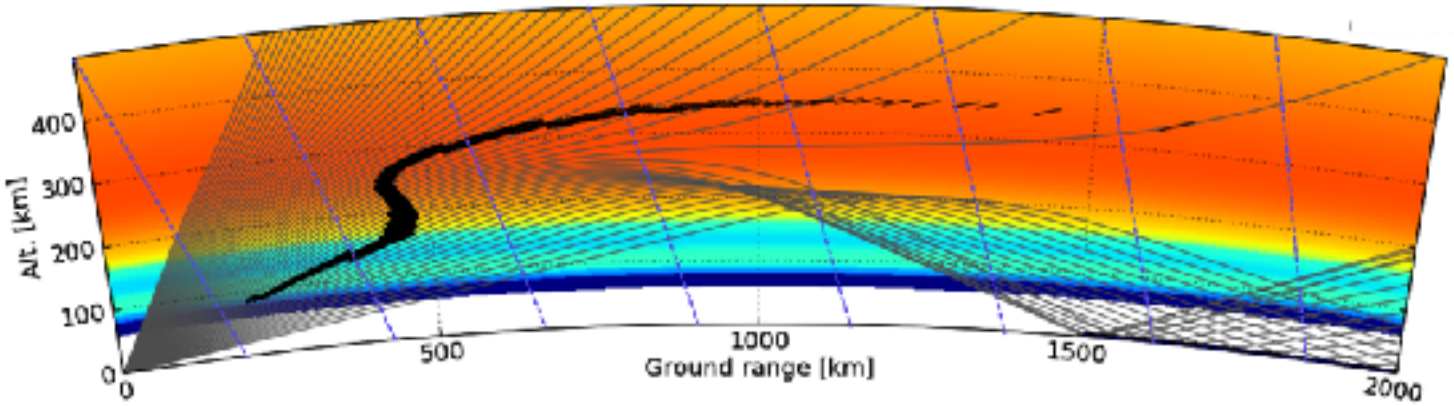
Acknowledgments

We are especially grateful for the

- support of NSF Grants AGS-2002278, AGS-1932997, AGS-1932972, AGS-2045755, AGS-2230345, and AGS-2230346.
- support of the NASA SWO2R Grant 80NSSC21K1772.
- support of Amateur Radio Digital Communication (ARDC).
- amateur radio community volunteers who have contributed to HamSCI projects.
- amateur radio community who voluntarily produced and provided the HF radio observations mentioned here, especially the operators of the Reverse Beacon Network (RBN, reversebeacon.net), the Weak Signal Propagation Reporting Network (WSPRNet, wsprnet.org), PSKReporter (pskreporter.info) qrz.com, and hamcall.net.
- use of the Free Open Source Software projects used in this analysis: Ubuntu Linux, python (van Rossum, 1995), matplotlib (Hunter, 2007), NumPy (Oliphant, 2007), SciPy (Jones et al., 2001), pandas (McKinney, 2010), xarray (Hoyer & Hamman, 2017), iPython (Pérez & Granger, 2007), and others (e.g., Millman & Aivazis, 2011).

One More Graph

15 MHz Raytrace Diagram



Questions?

Thank You!


THE UNIVERSITY OF
SCRANTON
A JESUIT UNIVERSITY
CASE WESTERN RESERVE UNIVERSITY
NJIT
New Jersey Institute of Technology
MIT
HAYSTACK
IAPR
NSF
ARDC