Eclipse Radio Science at NASA Marshall Space Flight Center

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NASA Marshall Space Flight Center, Huntsville, AL

HamSCI Workshop | February 23-24, 2018
NJIT, Newark NJ

The MSFC Eclipse Radio Science Team

Team:

Ghee Fry/WL7C	Heliophysics/Space Weather
Linda Rawlins	Retired NASA/Citizen Scientist
Jesse McTernan/KN4EZR	Heliophysics/Electrical Engineering
Rob Suggs/KB5EZ,	Space Environments/Meteoroids
Linda Krause/K0DRK	Heliophysics/Ionosphere/Space Weather
Dennis Gallagher	Heliophysics/Magnetospheres/Plasmaspheres
Mitzi Adams	Heliophysics/Public Outreach

Tools:

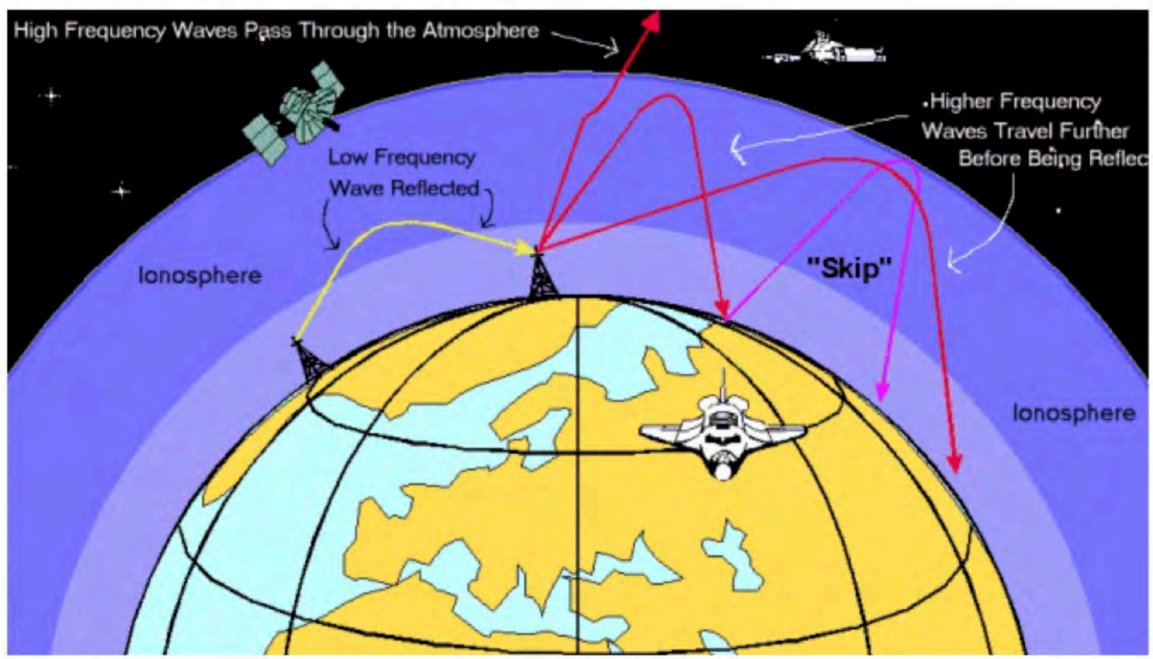
- Ham Shack Rigs, Computers and Antennas
- Reverse Beacon Network
- Weak Signal Propagation Reporter Network
- Amateur Radio Community

Ionospheric Radio Wave Propagation

Engaging students and citizen scientists

Lower frequencies (yellow),
Higher (red) frequencies
Different take-off angles

Propagation (radio wave path)

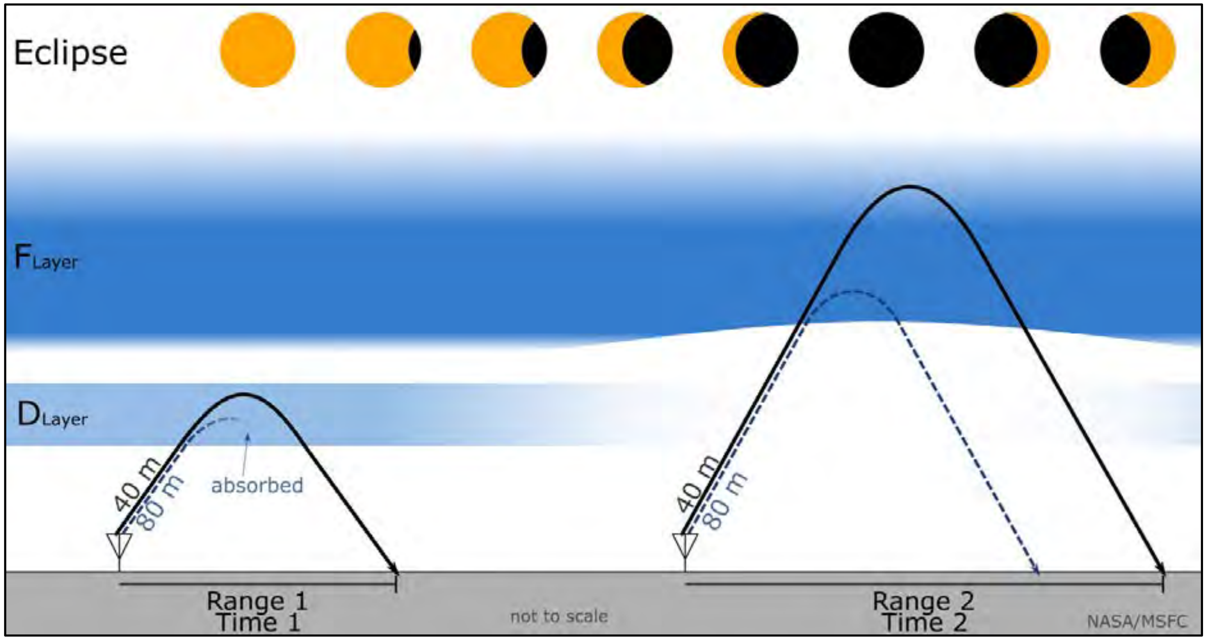


http://www.swpc.noaa.gov/phenomena/ionosphere

Eclipse Effects on Signal Path

- **Normal Summer Day:** (*ignoring a lot of electrodynamic processes, and no E-Region*)
  - D-Region absorbs 80M signals; 40M signals absorbed or signal strength decreases
- **Eclipse Day:** Solar EUV, X-rays decrease into eclipse; recovers out of eclipse
  - D-Region ionization reduced; ion-neutral recombination decreases electron density
  - Radio wave absorption decreases; 80M signals pass through D-Region
  - Erosion of lower F-Region raises ”reflection” height
  - Over-the-Horizon (OTH) signal paths lengthen; propagation range increases
  - Process reverses coming out of maximum eclipse

Left: Typical daytime signal paths.
Right: Signal paths during eclipse.
40M path —— 80M ----

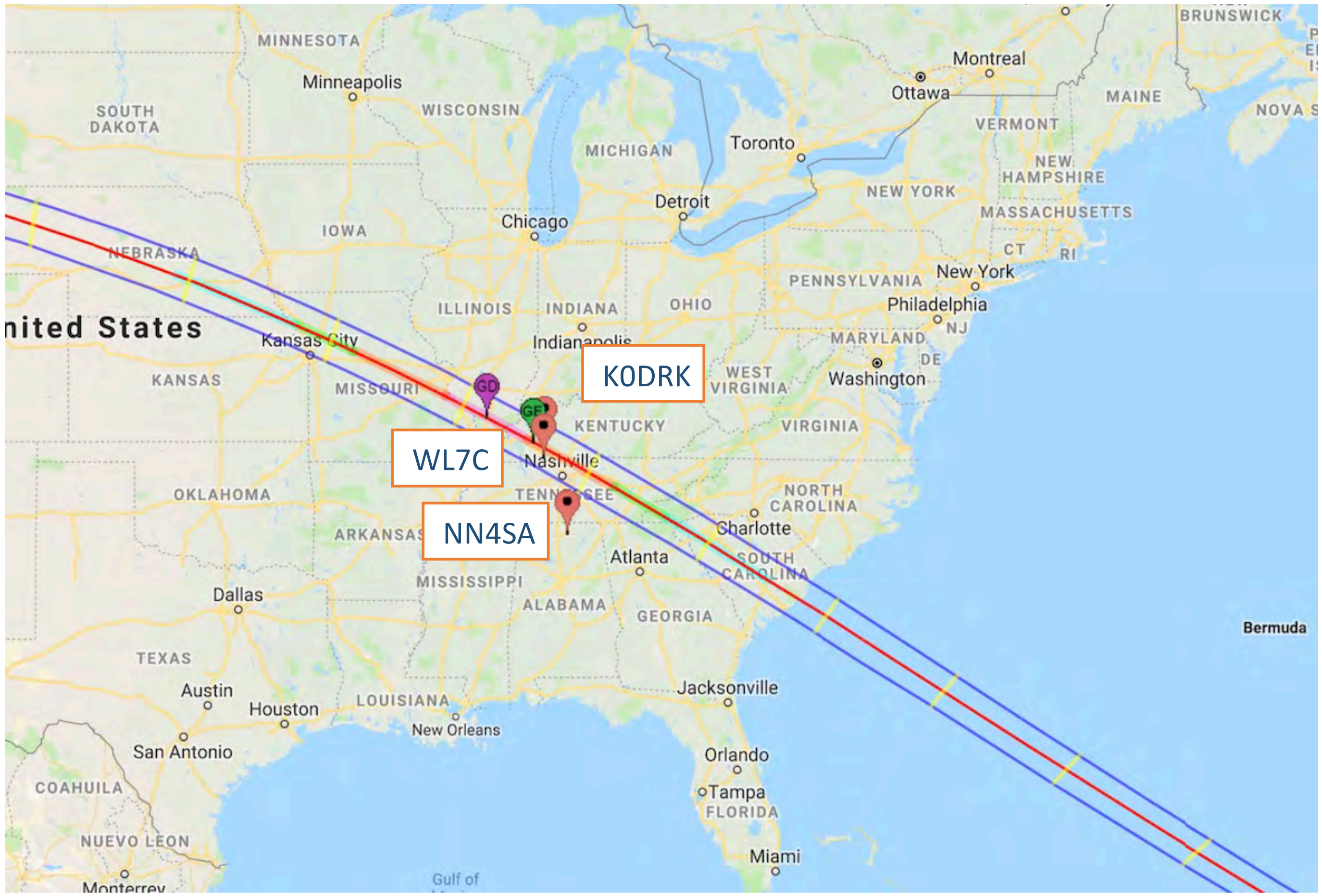


Station Locations

WL7C, Northern TN

K0DRK, Southern KY

NN4SA, Northern AL



https://eclipse.gsfc.nasa.gov/eclipse.html / Google Map Data © 2018 Terms of Use

WL7C and K0DRK near Greatest Eclipse; NN4SA Northern Alabama

WL7C Reverse Beacon Network Receiver/Skimmer

APSU Farm, Clarksville, TN (36.65N, 87.34W), Grid Square: EM66hn
South of eclipse centerline

RBN Skimmer in Cow Barn

Eclipse Details at APSU Farm Site

Table 1. Solar eclipse events at Austin Peay State University Observatory/Farm in Clarksville, TN, WL7C's RBN node location.

2017 Solar Eclipse
https://eclipse.gsfc.nasa.gov/SEgoogle/SEgoogle2001/SE2017Aug21Tgoogle.html

Lat.: 36.5623° N
Long.: 87.3386° W

Total Solar Eclipse
Duration of Totality: 2m24.1s
Magnitude: 1.009
Obscuration: 100.00%

Event	Date	Time (UT)	Alt	Azi
Start of partial eclipse (C1):	2017/08/21	16:57:03.2	62.4°	149.7°
Start of total eclipse (C2):	2017/08/21	18:25:32.0	64.2°	198.9°
Maximum eclipse:	2017/08/21	18:26:44.1	64.1°	199.6°
End of total eclipse (C3):	2017/08/21	18:27:56.1	64.0°	200.2°
End of partial eclipse (C4):	2017/08/21	19:52:29.0	53.4°	235.2°

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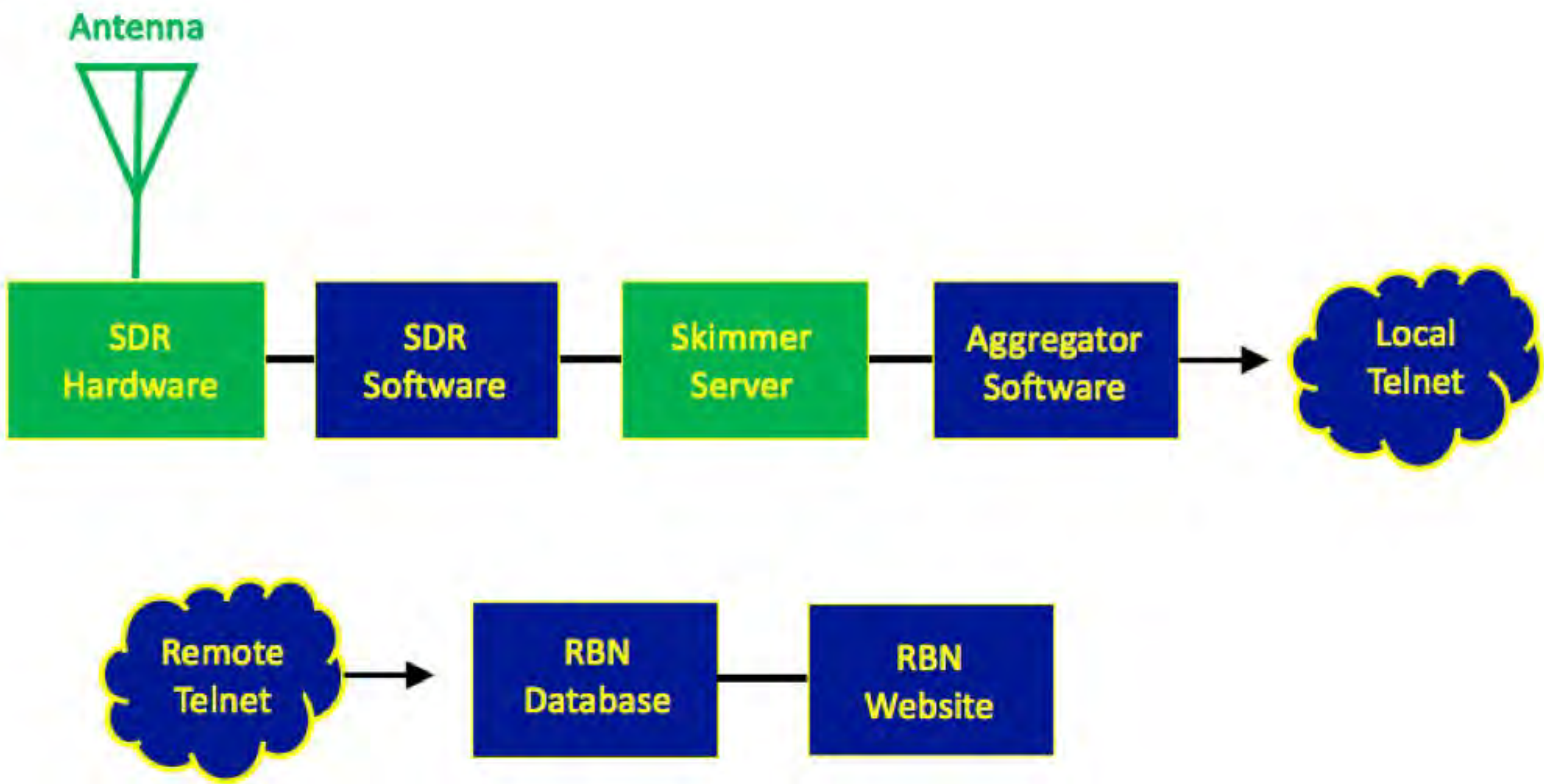
WL7C Reverse Beacon Network Skimmer

APSU Farm, Grid Square: EM66hn



Setting up WL7C at APSU

WL7C RBN Site and Antenna

82-foot DXE Alpha Delta fan dipole antenna for 80M, 40M, 20M, 10M

K0DRK Reverse Beacon Network Transmitter

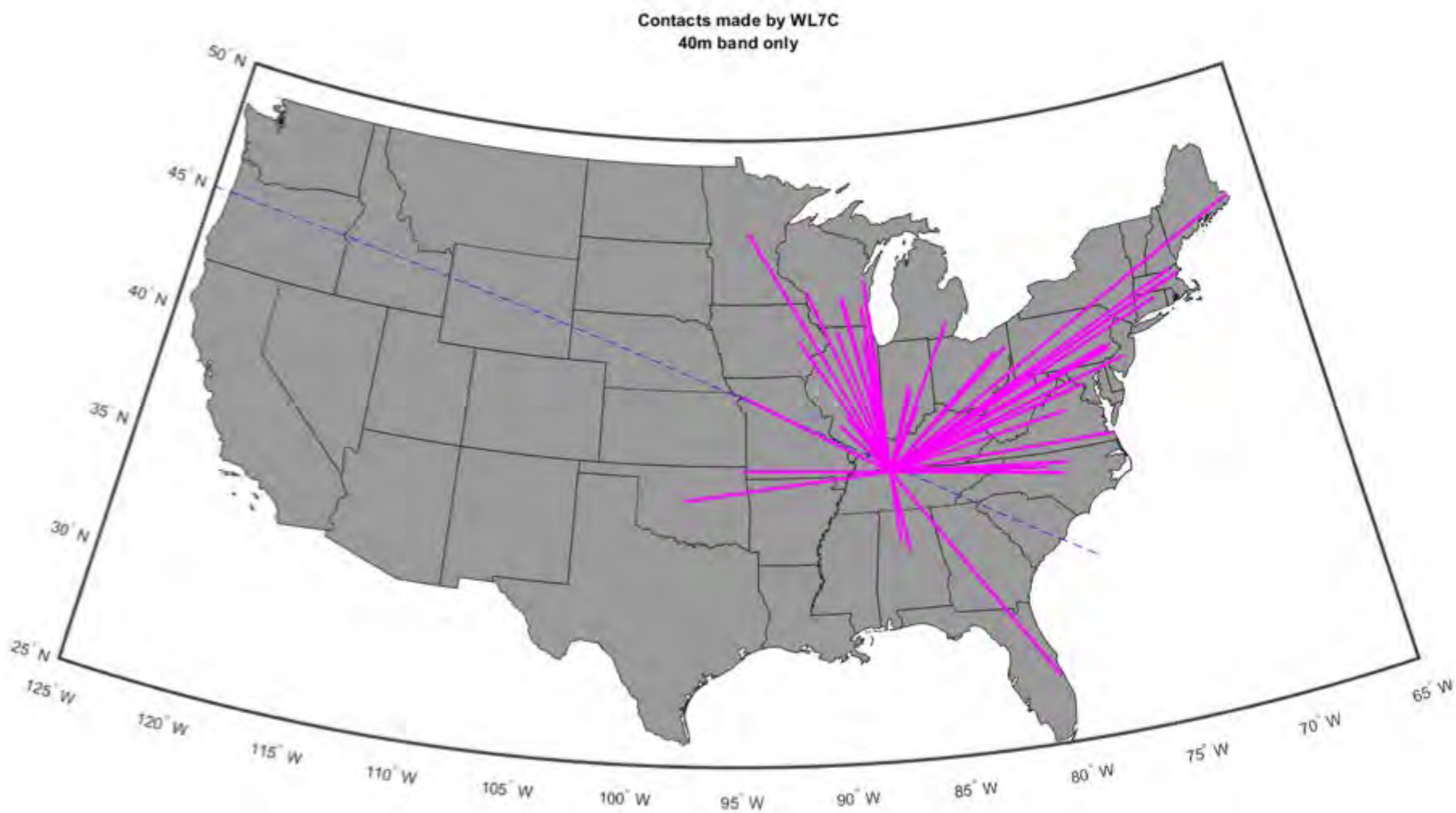
North of eclipse centerline

K0DRK Reverse Beacon Network Transmitter
North of Hopkinsville, KY (37.04N, 87.30W)
Near eclipse centerline; Grid Square: EM67ia
80 watts feeding 10-80M Alpha Antenna

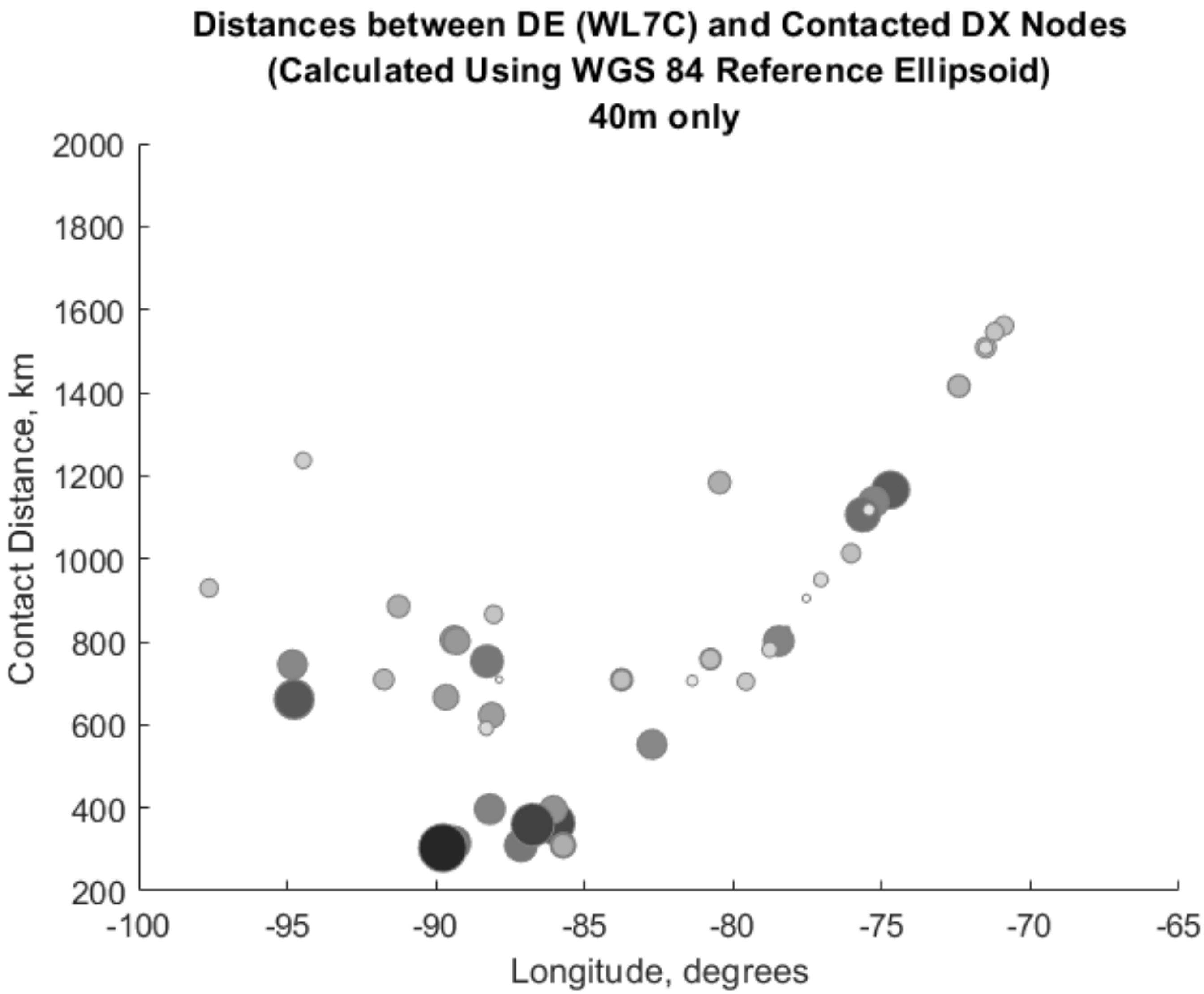
WL7C 40M Propagation Paths

August 21, 2017: Day of Eclipse

Propagation paths of stations received by WL7C August 21, 2017 between 1400-2000 UT. WL7C is at the apparent radiant point.

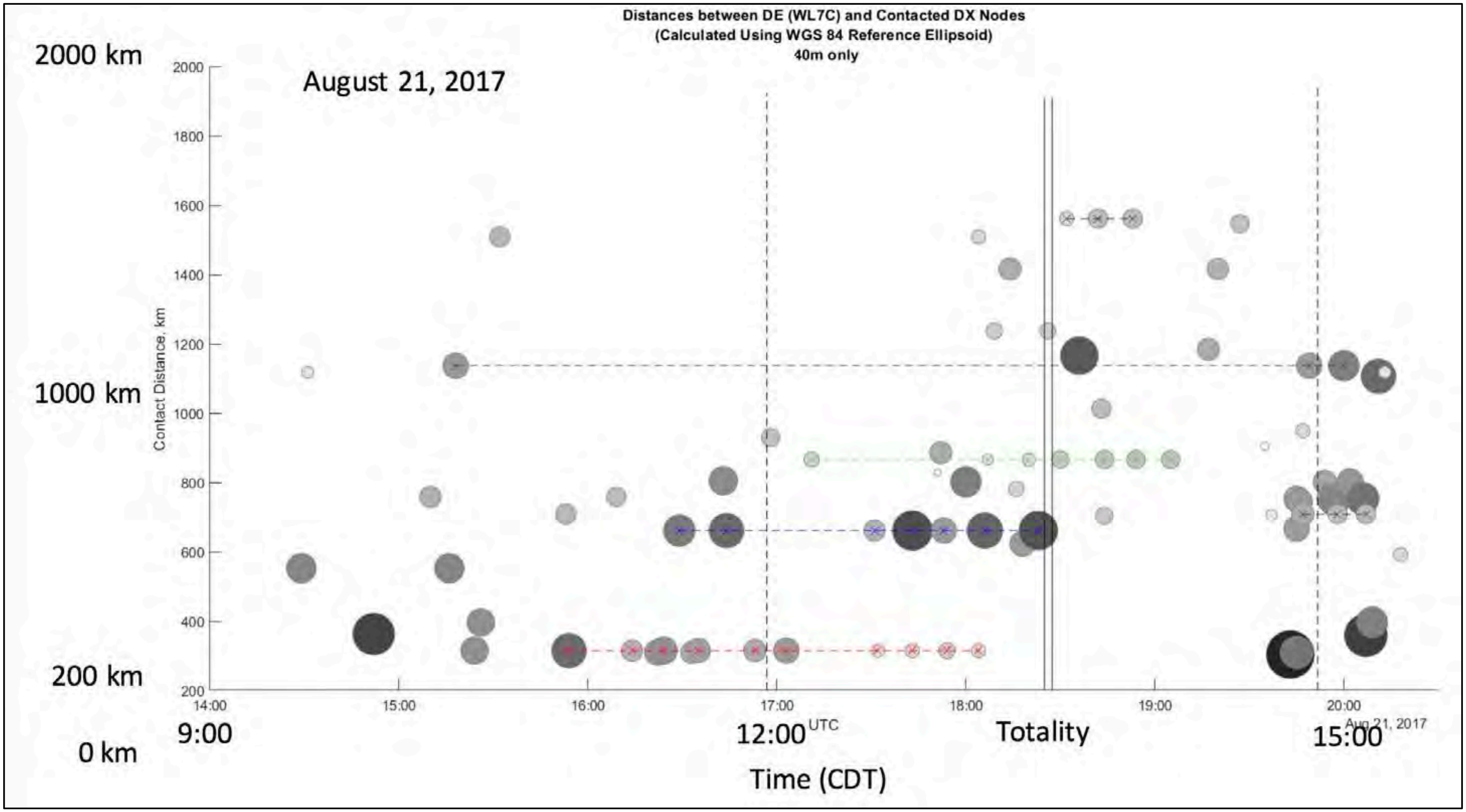


WL7C Spots: GCD Distance vs Longitude



WL7C 40M (7.0 MHz): Contact Distance vs. Time

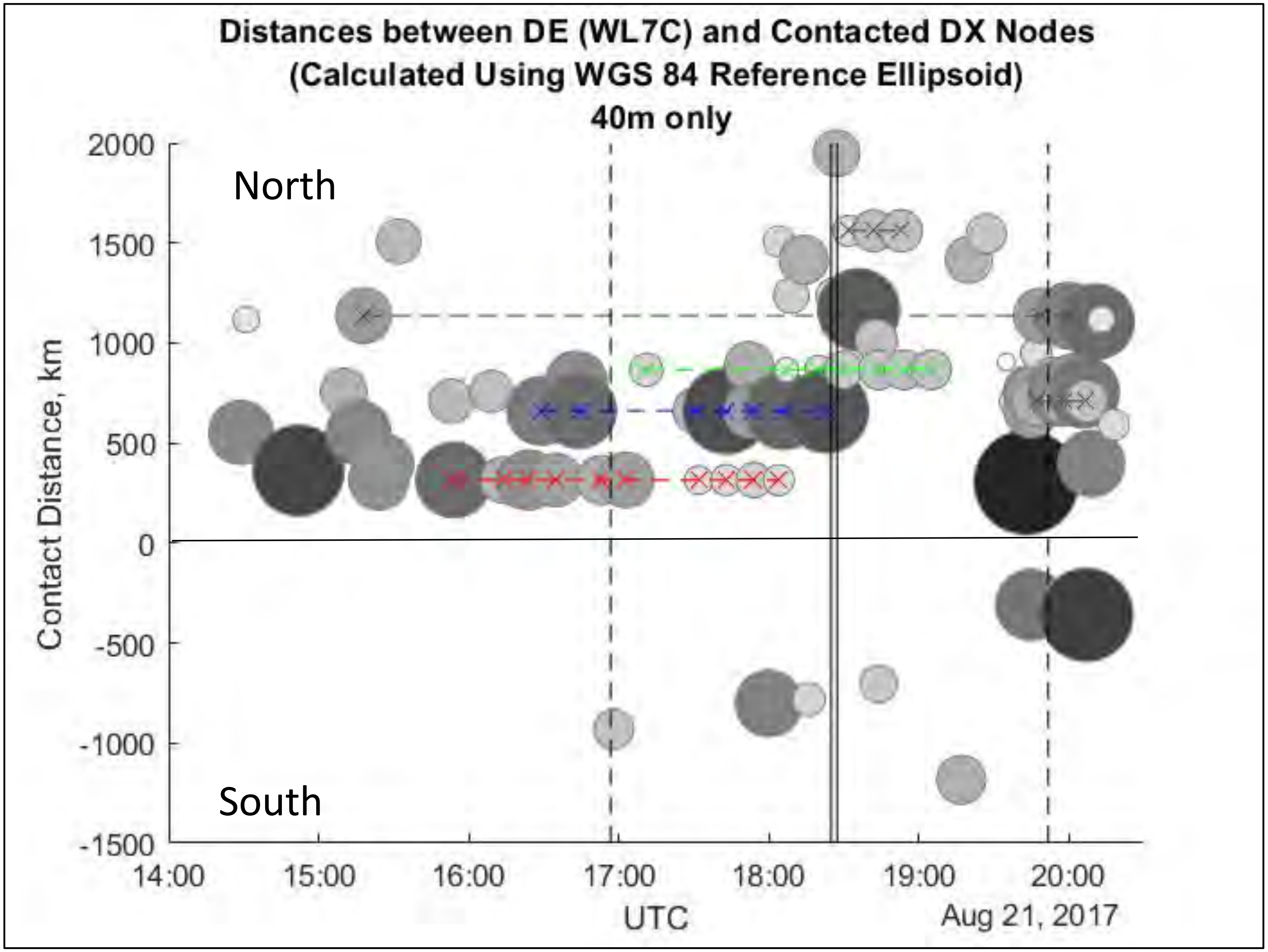
Day of Eclipse, August 21, 9:00-15:00 CDT



Colored lines represent spots from same station

WL7C Spots GCD Distance vs time

Day of Eclipse, August 21, 9:00-15:00 CDT



Colored lines represent spots from same station

NN4SA Weak Signal Propagation Reporter Transmitters

Marshall Amateur Radio Club (MARC) Station
NASA Marshall Space Flight Center
Huntsville, AL (34.64N, 86.68W),
Grid Square: EM64qp
Partial eclipse (96.5% obscuration)
5 watt transmitters on 80M and 40M

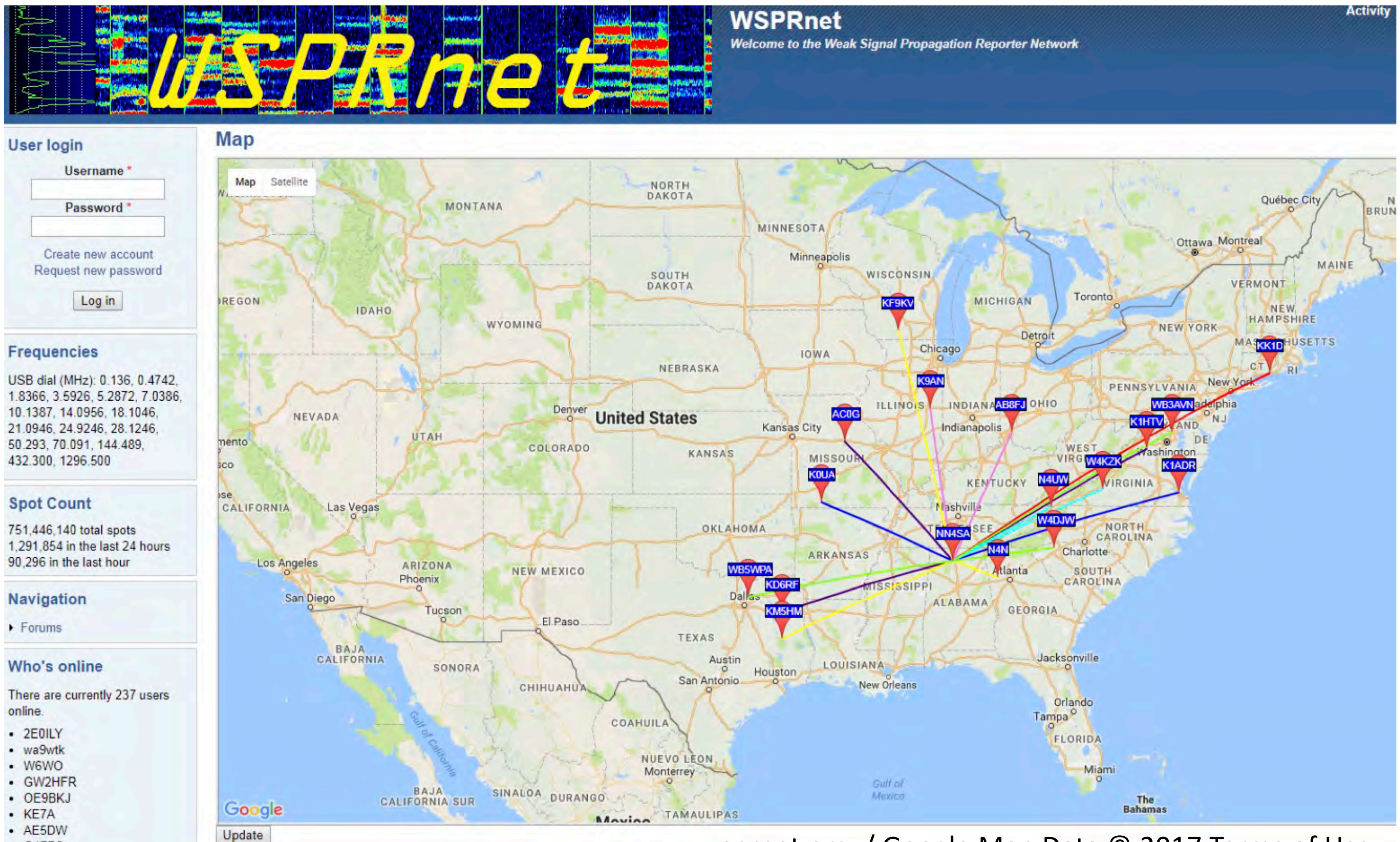
Weak Signal Propagation Reporter Map 8-21-17

Courtesy Robb Suggs, KB5EZ

NN4SA WSPR Propagation Paths – 80M band (3.5 MHz)

Red pins represent stations receiving NN4SA

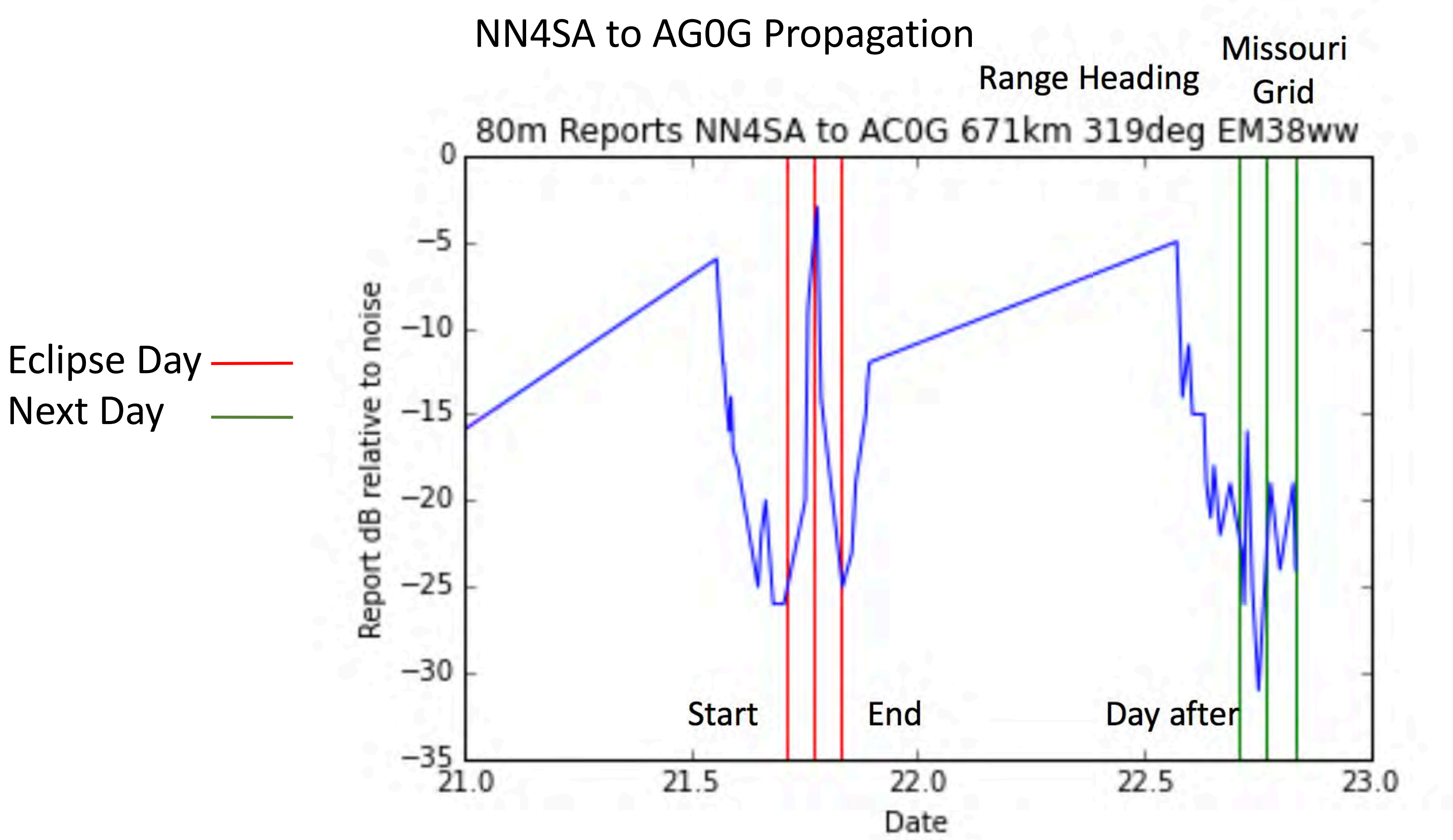
NN4SA at radiant in North Alabama



wsprnet.org / Google Map Data © 2017 Terms of Use

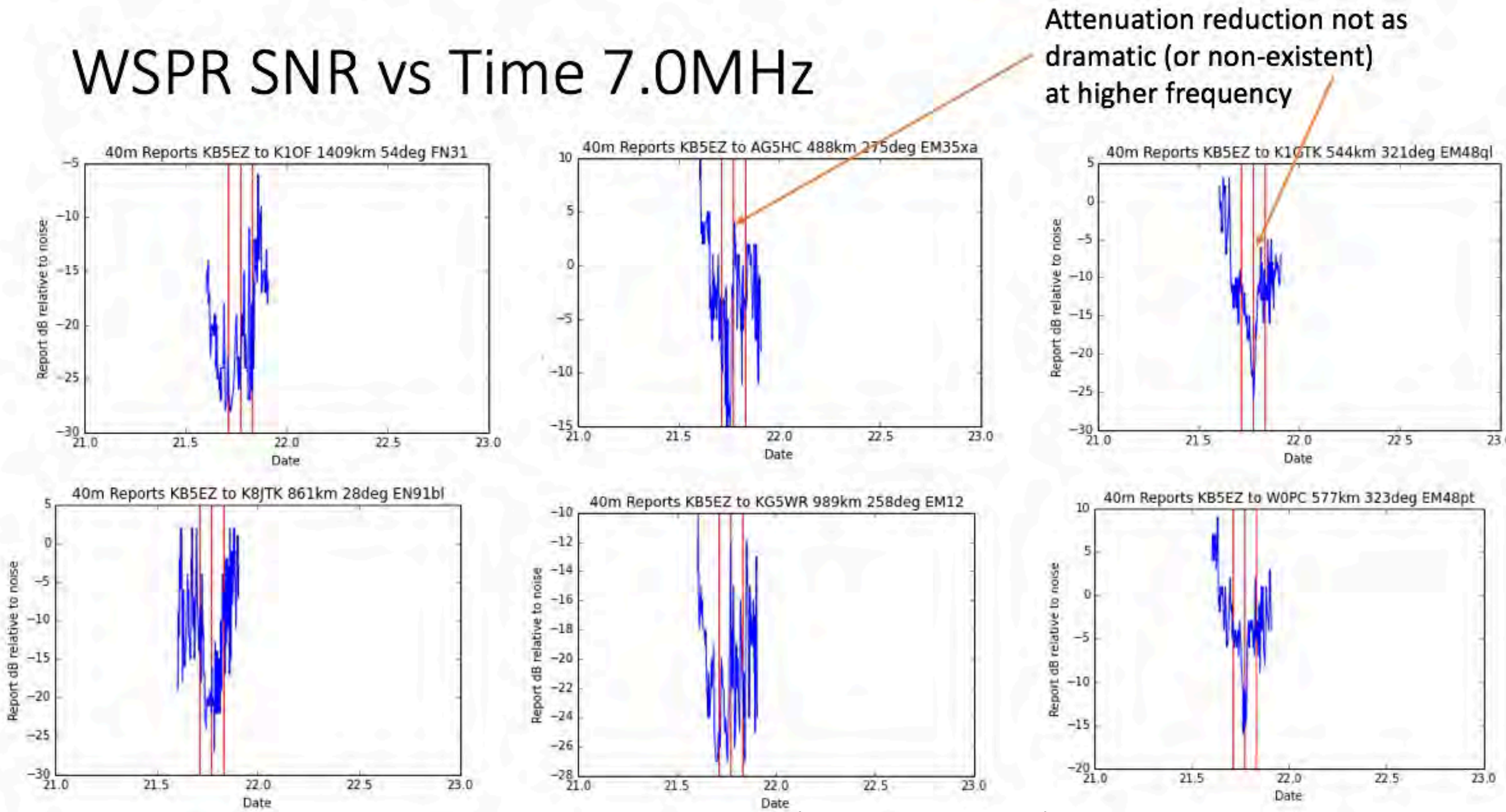
80M (3.5 MHz) Signal to Noise Ratio vs Time

Courtesy Robb Suggs, KB5EZ



NN4SA WSPR 40M Transmitter Reception

Figure courtesy Robb Suggs, KB5EZ

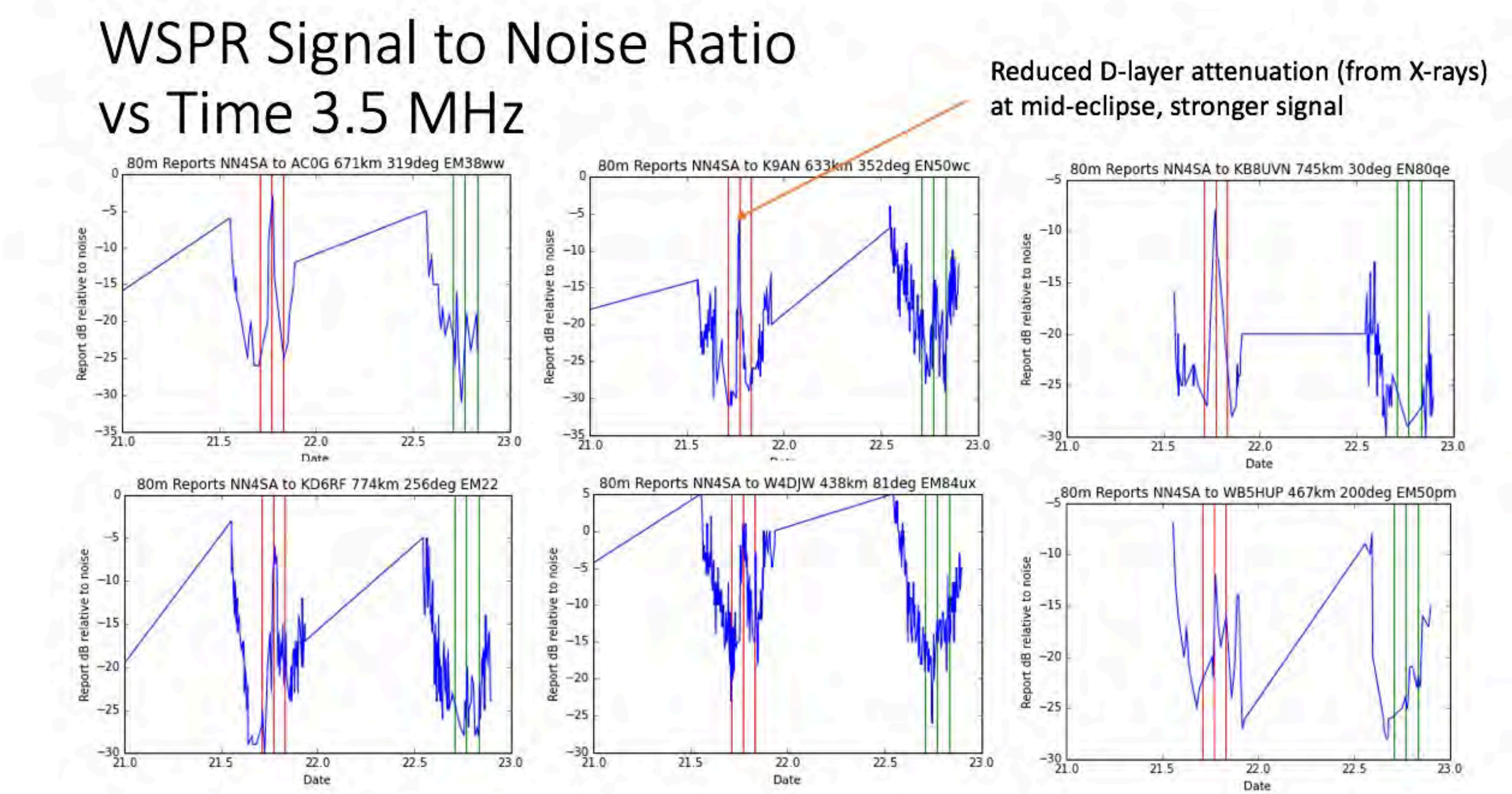


MSFC, Huntsville, AL (34.64N, 86.68W)

Reports of SNR on 40M by six WSPR stations showed enhancements of signals during the eclipse (red lines), but not on the day after (green lines). Figures indicates the range and azimuth from the NN4SA transmitter.

NN4SA WSPR 80M Transmitter Reception

Figure courtesy Robb Suggs, KB5EZ



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Why Didn't WL7C Hear K0DRK?

On the day of the eclipse, why didn't WL7C hear K0DRK on 40M just 30 miles (53 km) away?

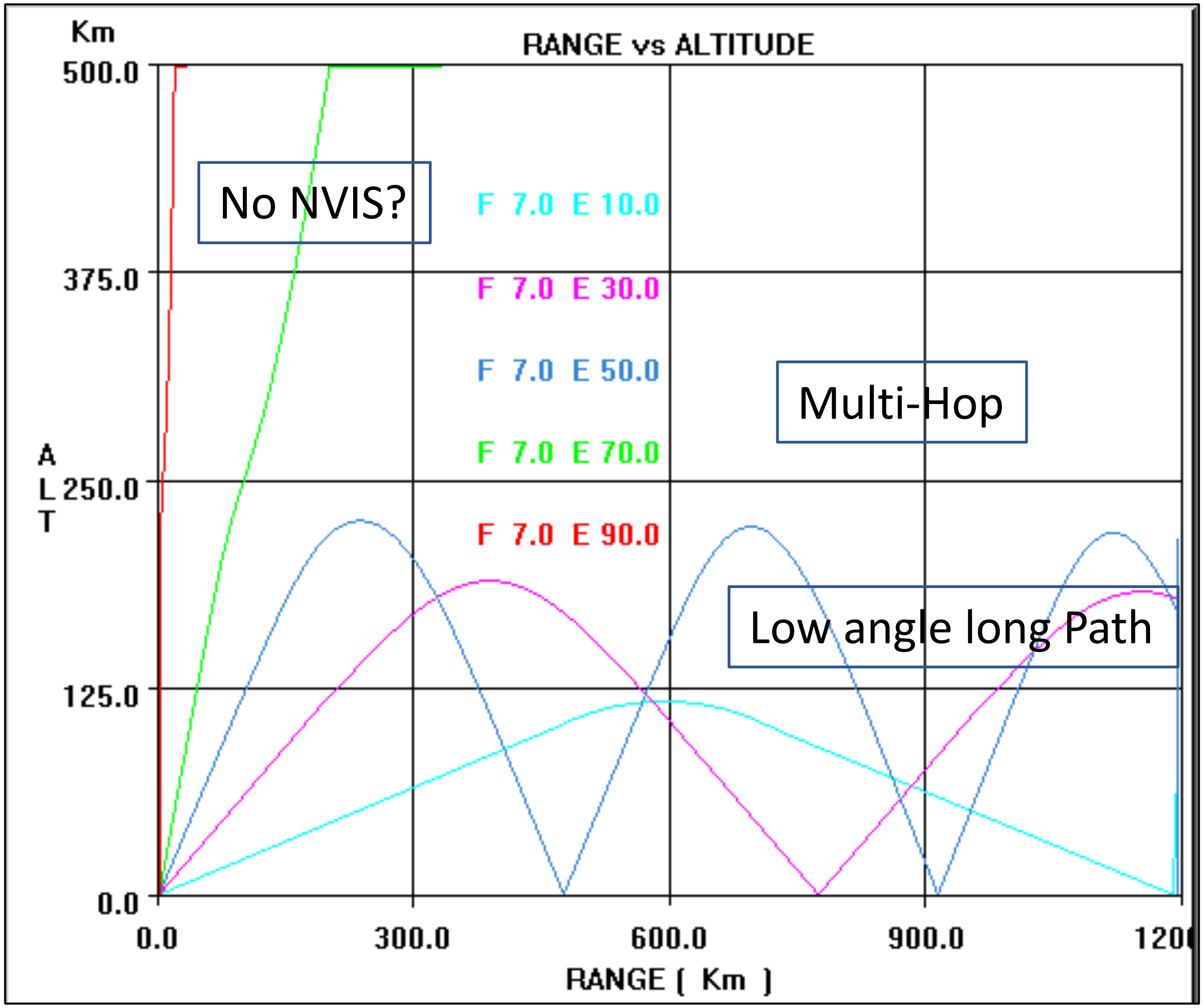
- Line of Sight?
  - Terrain and Distance over the horizon
- Ground Wave?
  - Distance, soil conductivity
- Near Vertical Ionospheric Skywave (NVIS)?
  - *foF2*, was near 4.0 MHz +/- 0.5 MHz,
  - *hmF2*, height of F2 layer peak, ranging 196-244 km.
- PIM says no

Parameterized Ionospheric Model (PIM)
40M Mid-Latitude Ray Traces

7.0 MHz radio wave ray paths at different elevation (take-off) angles (E)

F = Frequency
E = elevation angle

foF2 ~ 3.5 - 4.5 MHz,
hmF2 ~ 196-244 km.



Conclusions and Lessons Learned

Conclusions

- 2017 total solar eclipse demonstrated that HF radio science can be done:
  - On a shoestring budget
  - By professional, citizen scientists, students and the amateur radio community
  - Using grass roots crowd-sourced propagation spot aggregators (e.g., RBN, WSPR)

Lessons Learned

- Data quality can be impacted by the social nature of crowd-sourced observations: accuracy of location, timing, consistency
- Do the site survey BEFORE the eclipse !
- Radio Science is FUN !

Next Steps

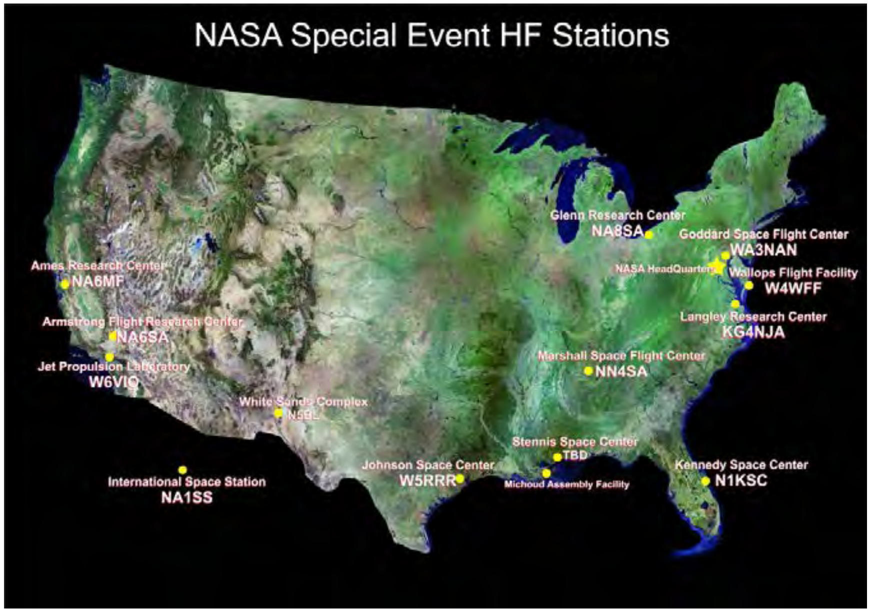
- Improving ionospheric radio science capabilities:
  - Install RBN CW Skimmer and WSPR receivers at MSFC/NSSTC Upgrade SDR hardware, software, site location*
  - Continue to engage Hams, students and citizen scientists
- Preparing for the next Big Eclipse opportunity
  - Chile, 2019 (?)
  - Mexico/USA 2024

NASA/MSFC Postdoc Jesse McTernan/KN4EZR's Talk for details

Thanks to ARRL, Virginia Tech and academic community, HamSCI, the Solar Eclipse QSO Party participants and especially the curators and volunteers of RBN and WSPRnet and other spot aggregator sites

NASA On The Air

- Apollo 17 45th anniversary – 11-19 December 2017, beginning of event
- NASA founded 60th anniversary (act signed by President Eisenhower) – 29 July 1958
- ISS First Element Launch 20th anniversary – 20 November 1998
- ISS Node 1 Launch 20th anniversary – 4 December 1998
- 50th anniversary of Apollo 8 – launch 21 December 1968
- Apollo 8 – splashdown 27 December 1968, end of event



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https://nasaontheair.wordpress.com