

# Eclipse Radio Science at NASA Marshall Space Flight Center



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Linda Rawlins

NASA Marshall Space Flight Center, Huntsville, AL

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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:

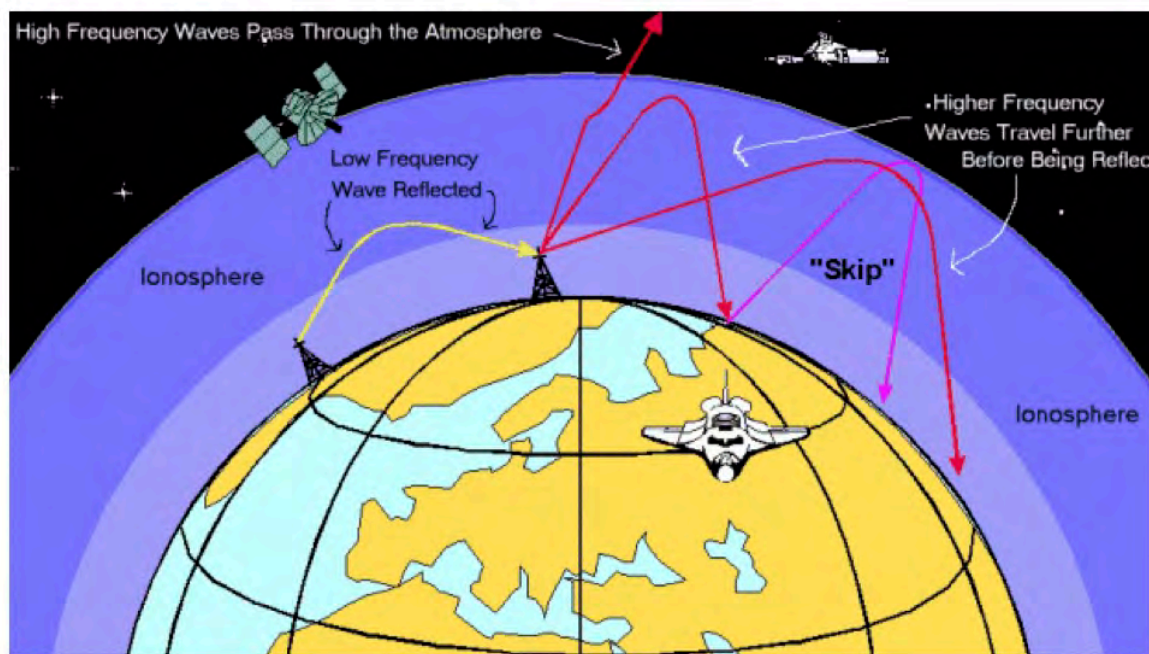
- Ham Shack Rigs, Computers and Antennas
- Reverse Beacon Network
- Weak Signal Propagation Reporter Network
- Amateur Radio Community

# Ionospheric Radio Wave Propagation

Engaging students and citizen scientists

Propagation (radio wave path)

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

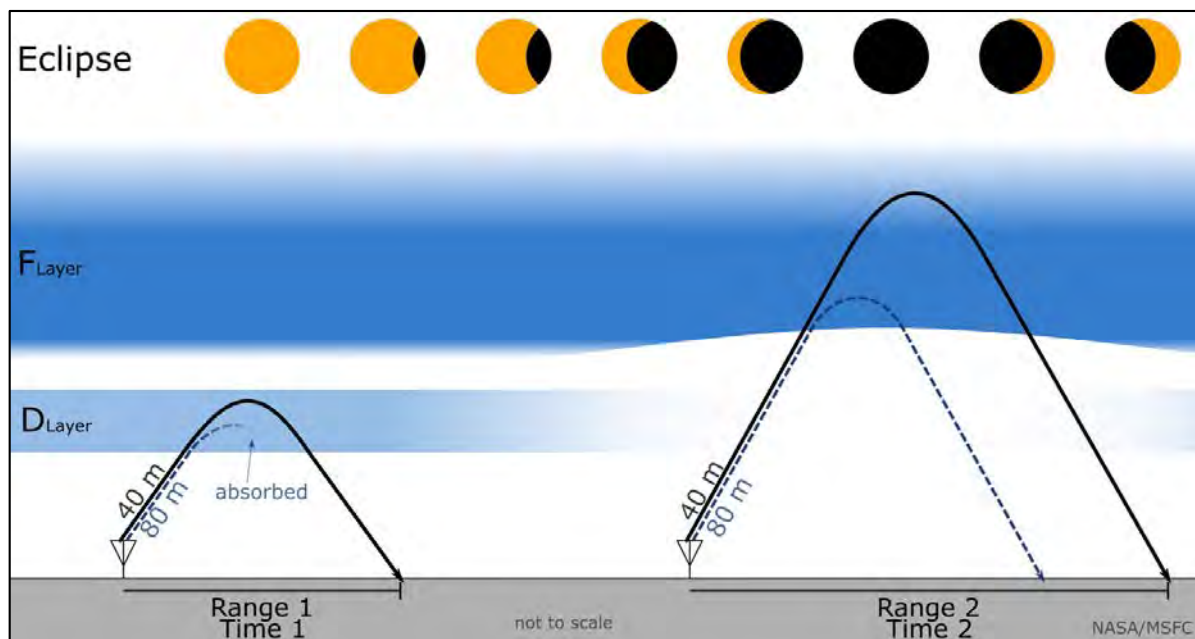


<http://www.swpc.noaa.gov/phenomena/ionosphere>

# 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 ----

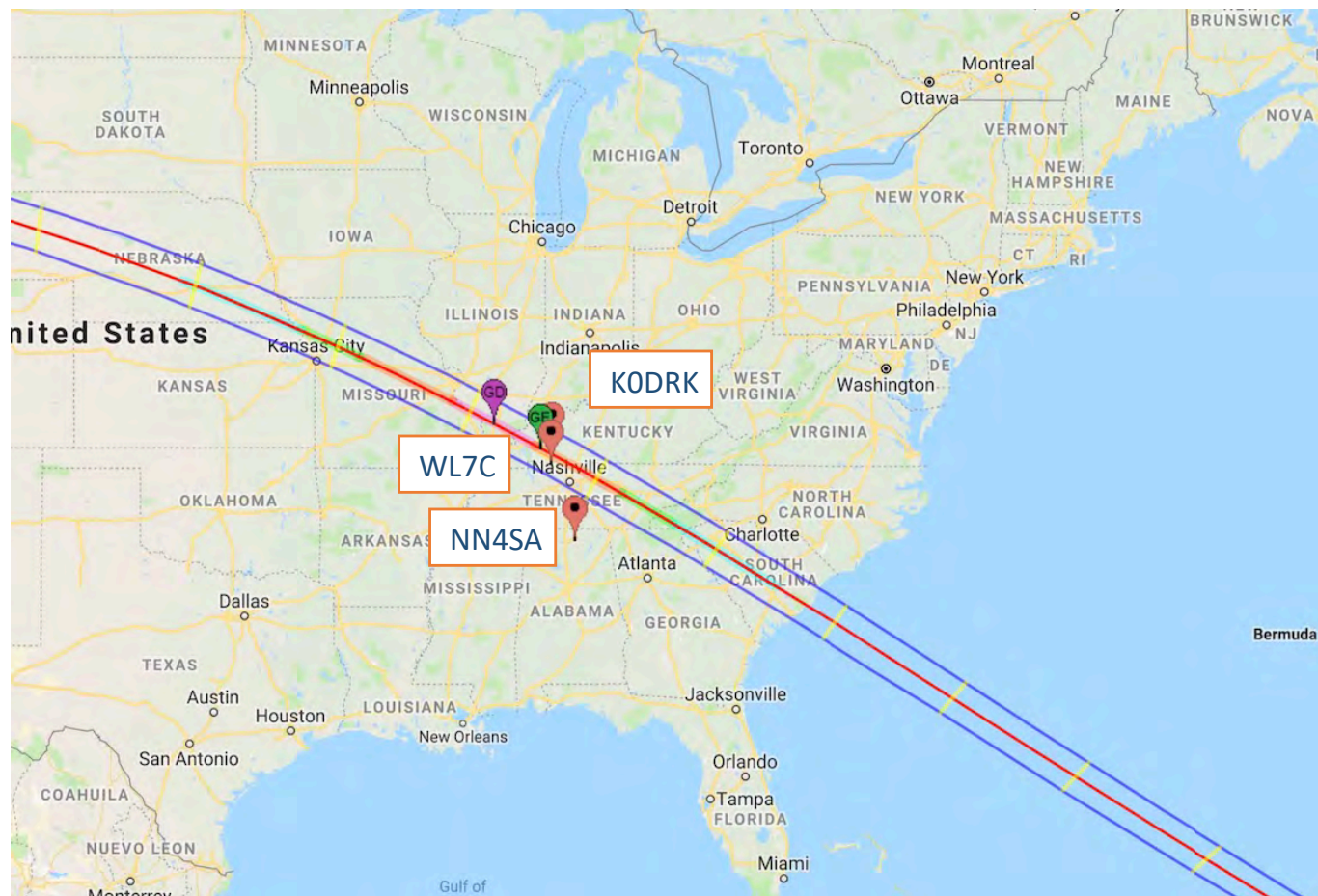


# Station Locations

WL7C, Northern TN

KODRK, Southern KY

NN4SA, Northern AL



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

WL7C and KODRK 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

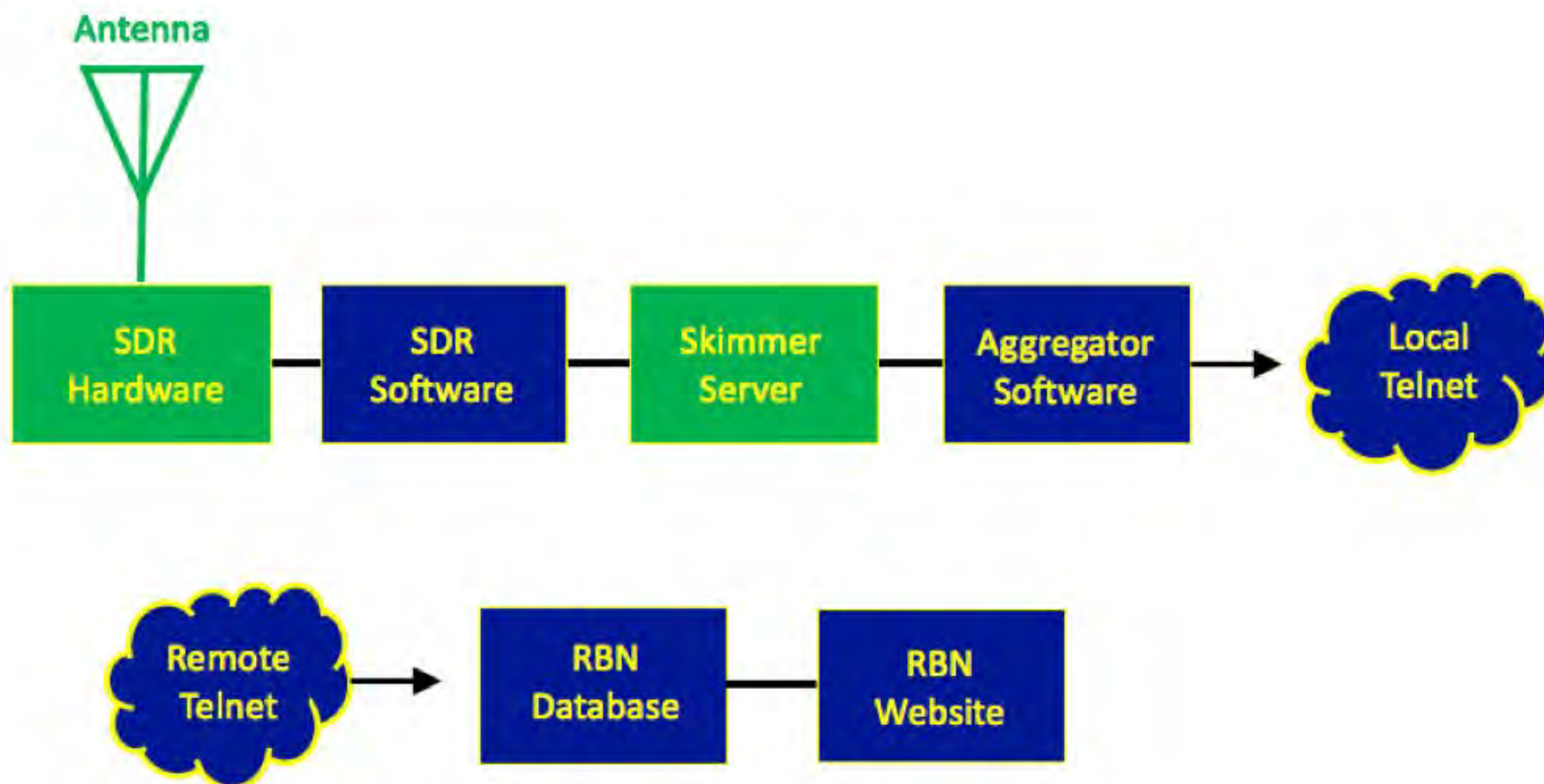
Obscuration: 100.00%

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°

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

# 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

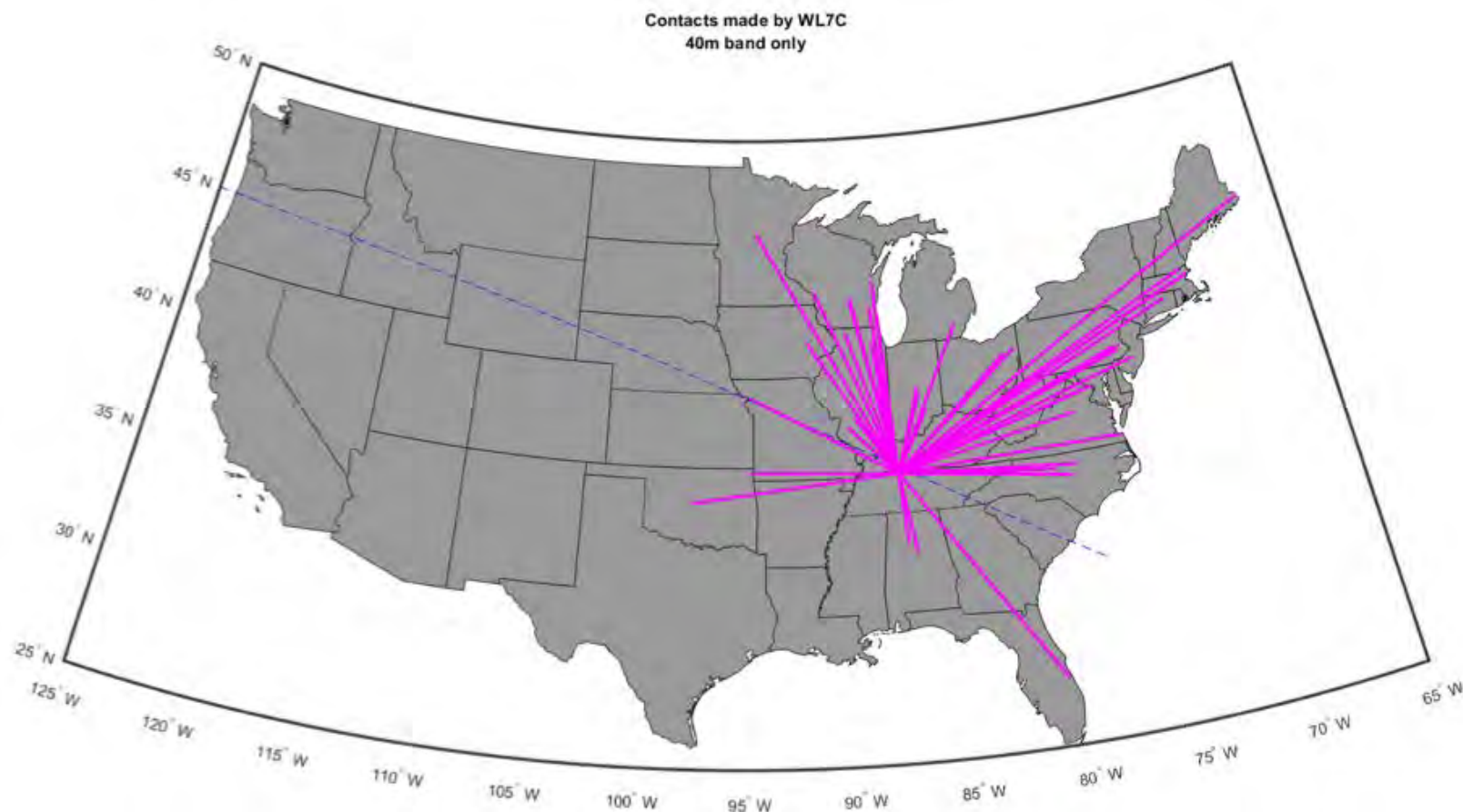




# WL7C 40M Propagation Paths

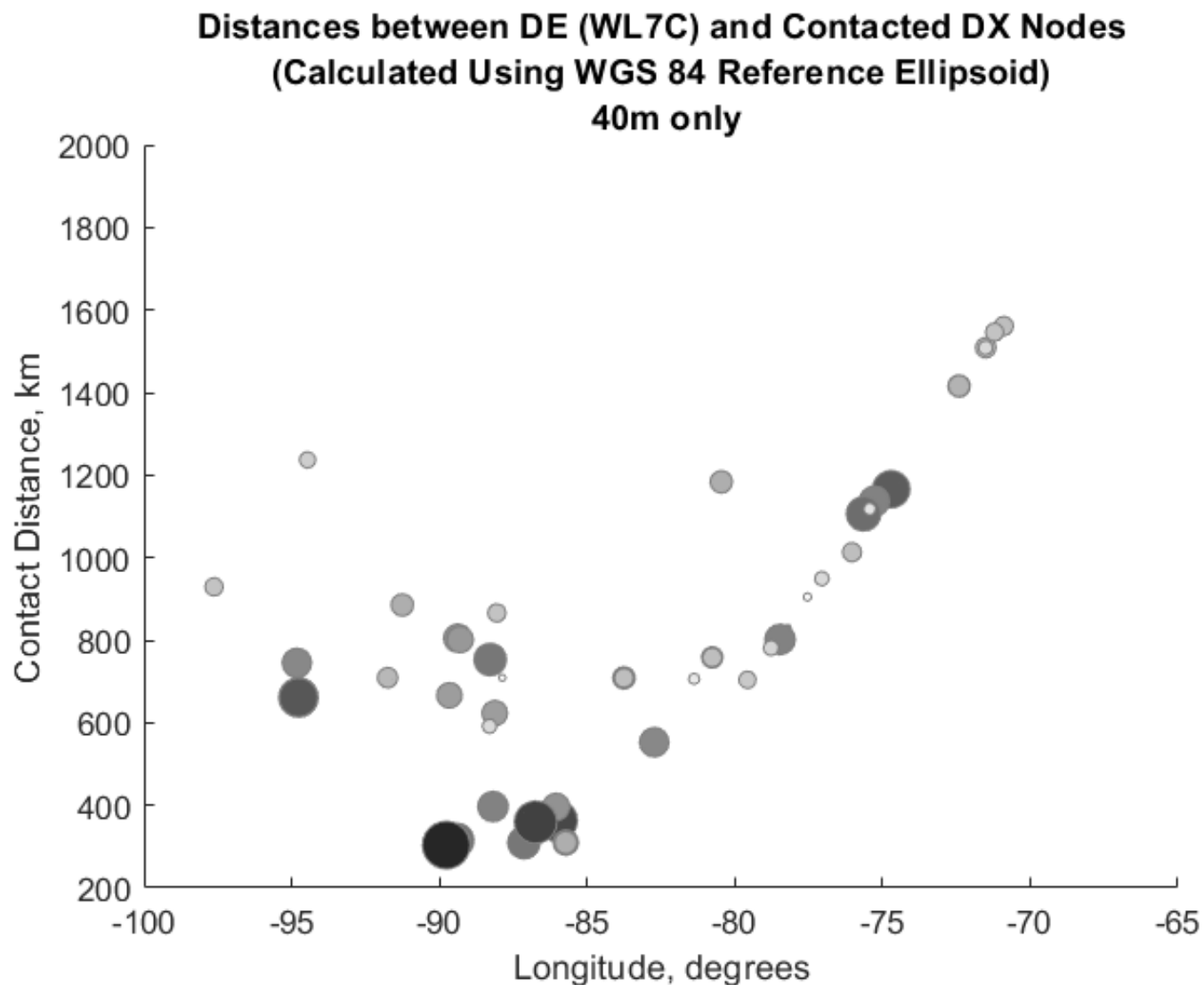
August 21, 2017: Day of Eclipse

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



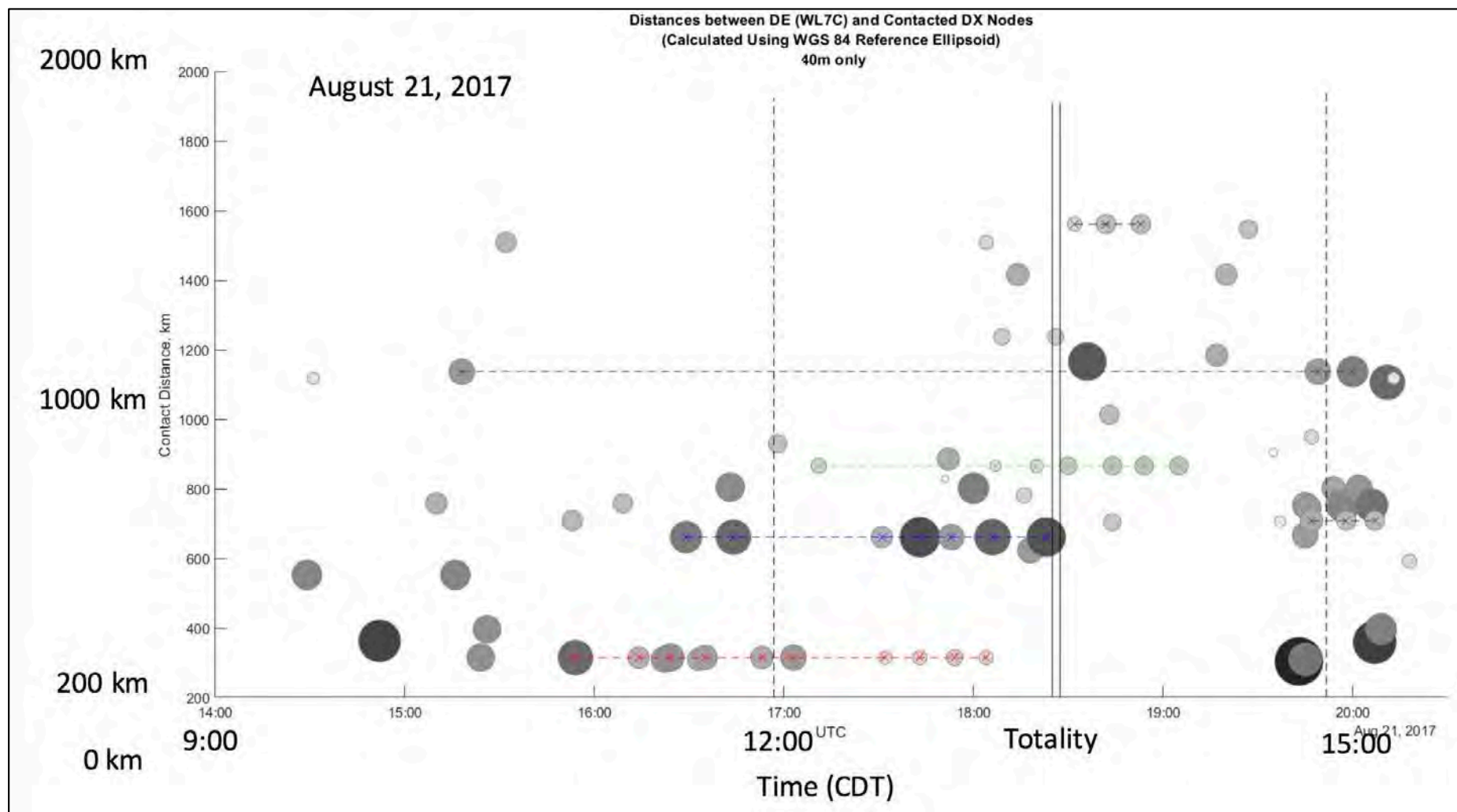


# WL7C Spots: GCD Distance vs Longitude



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

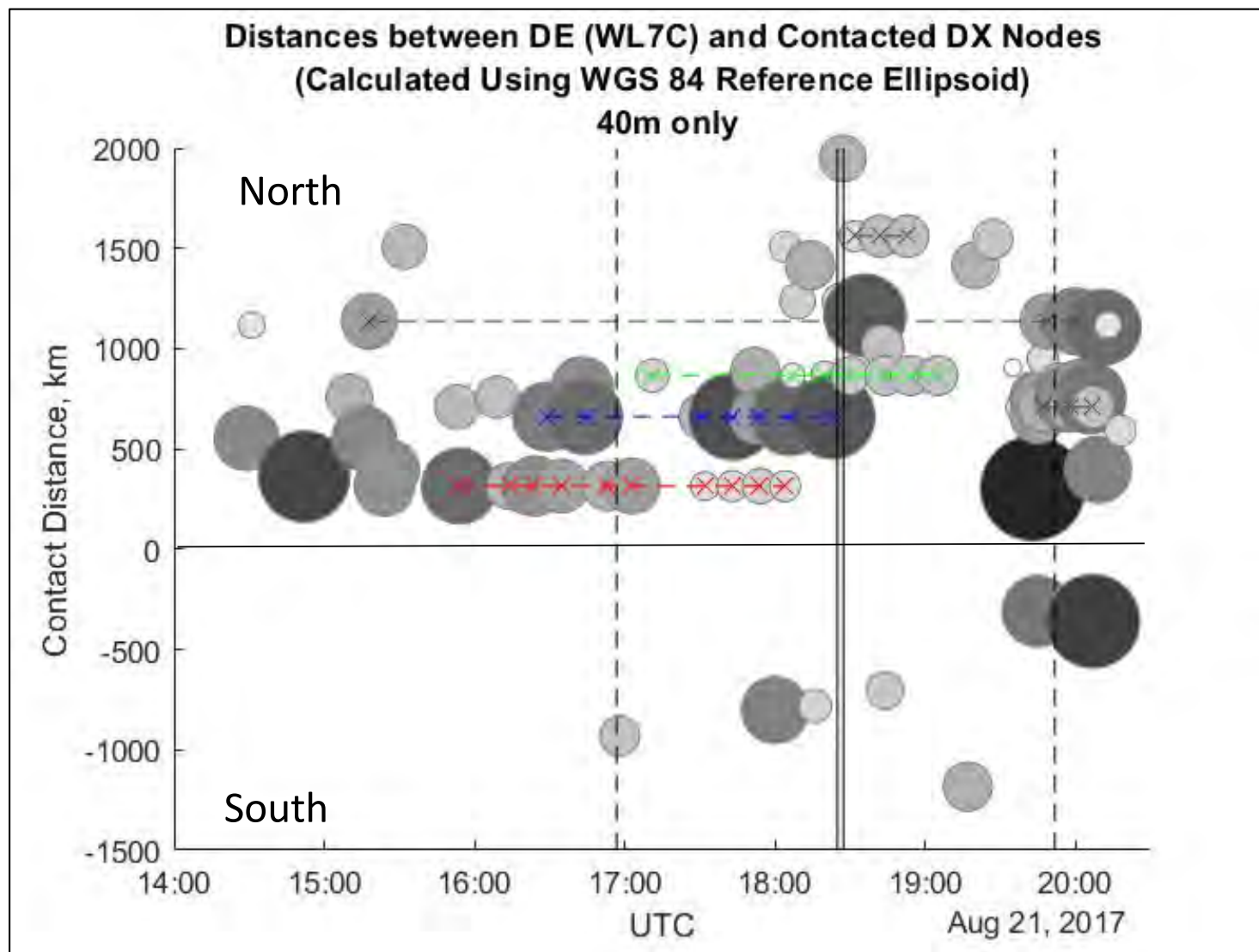
Day of Eclipse, August 21, 9:00-15:00 CDT



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



NN4SA



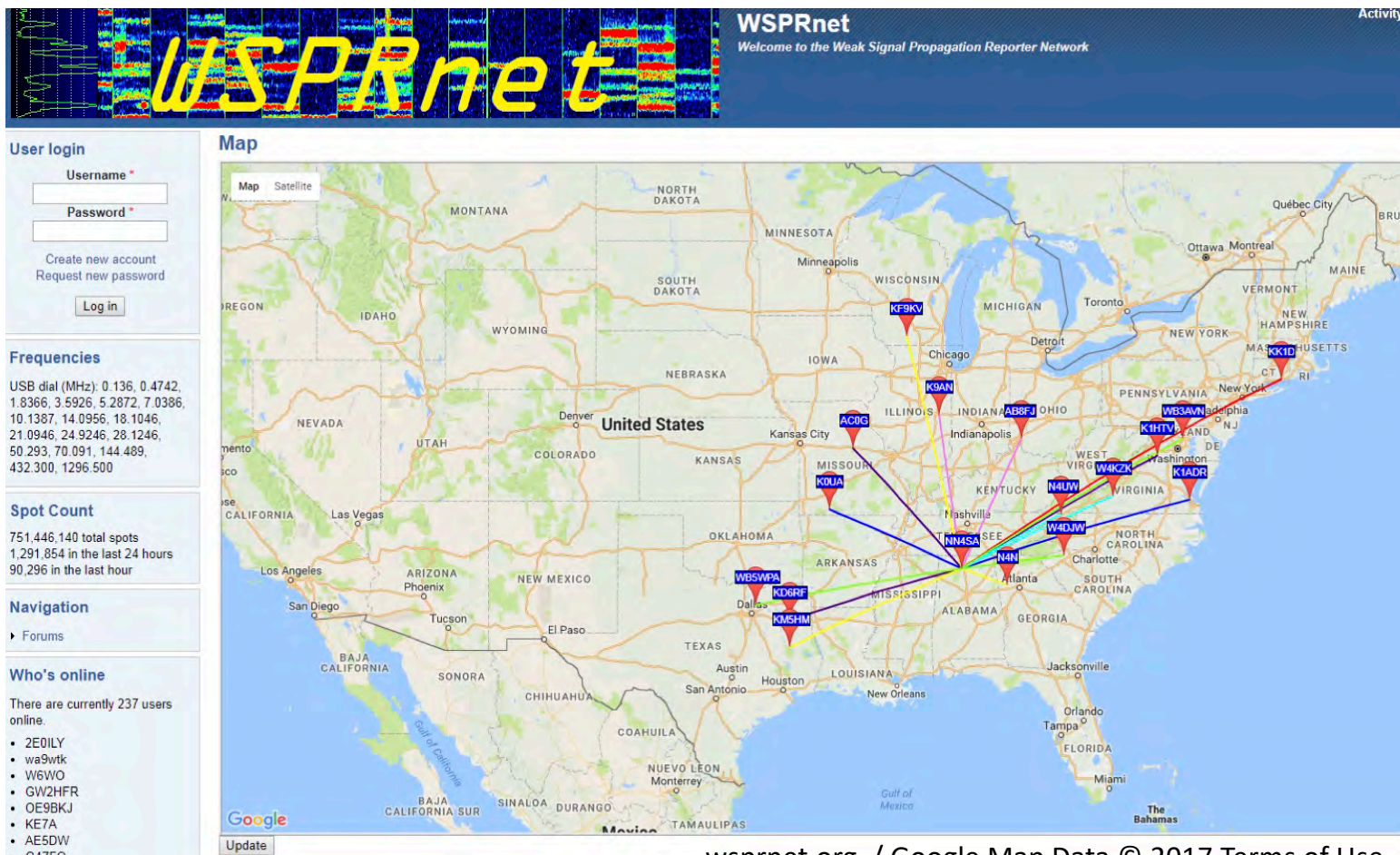
Marshall Amateur Radio Club (MARC) Station  
NASA Marshall Space Flight Center  
Huntsville, AL (34.64N, 86.68W),  
Grid Square: EM64qp  
Partial eclipse (96.5% obscuration)  
5 watt transmitters on 80M and 40M



# Weak Signal Propagation Reporter Map 8-21-17

Courtesy Robb Suggs, KB5EZ

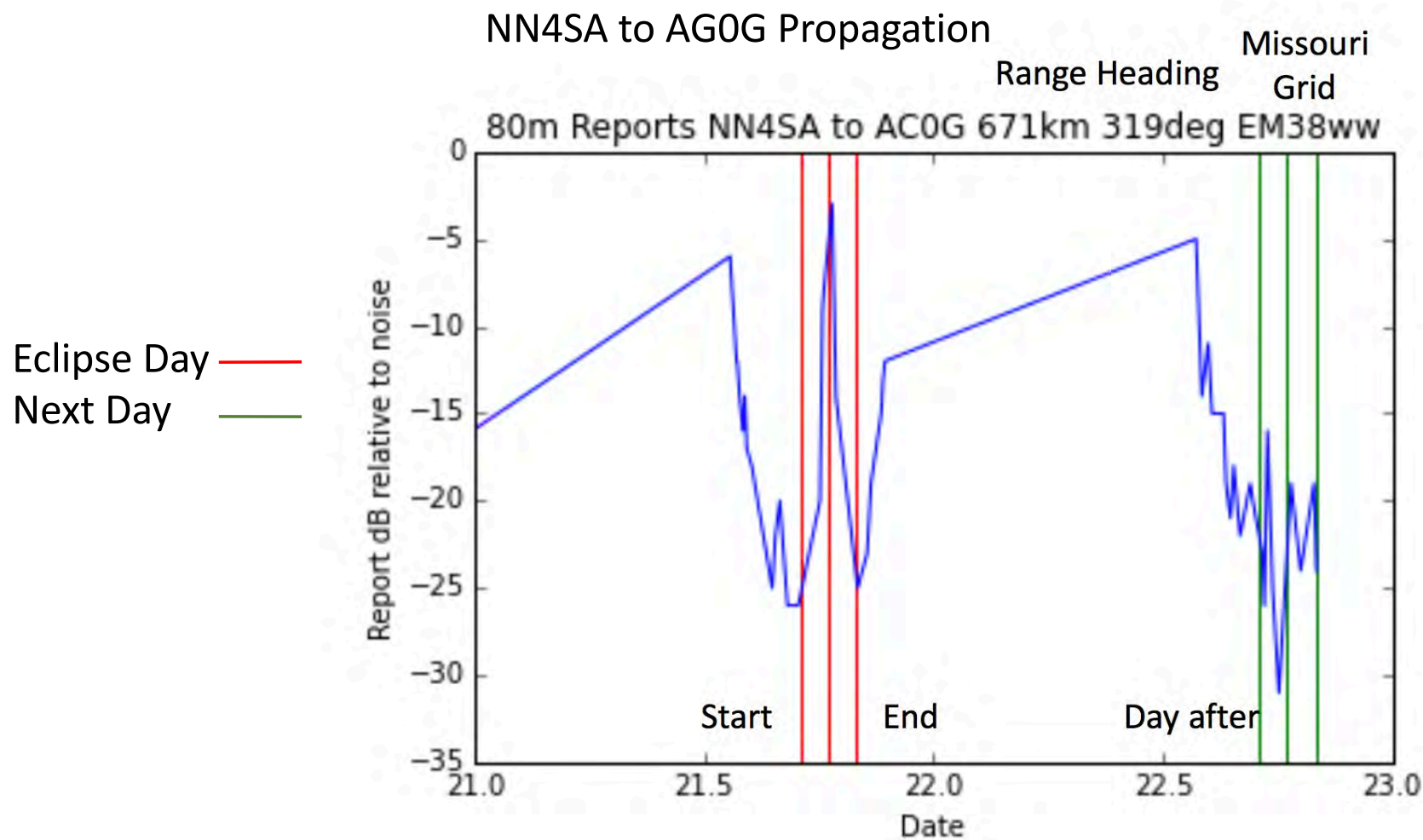
## NN4SA WSPR Propagation Paths – 80M band (3.5 MHz)



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

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

Courtesy Robb Suggs, KB5EZ

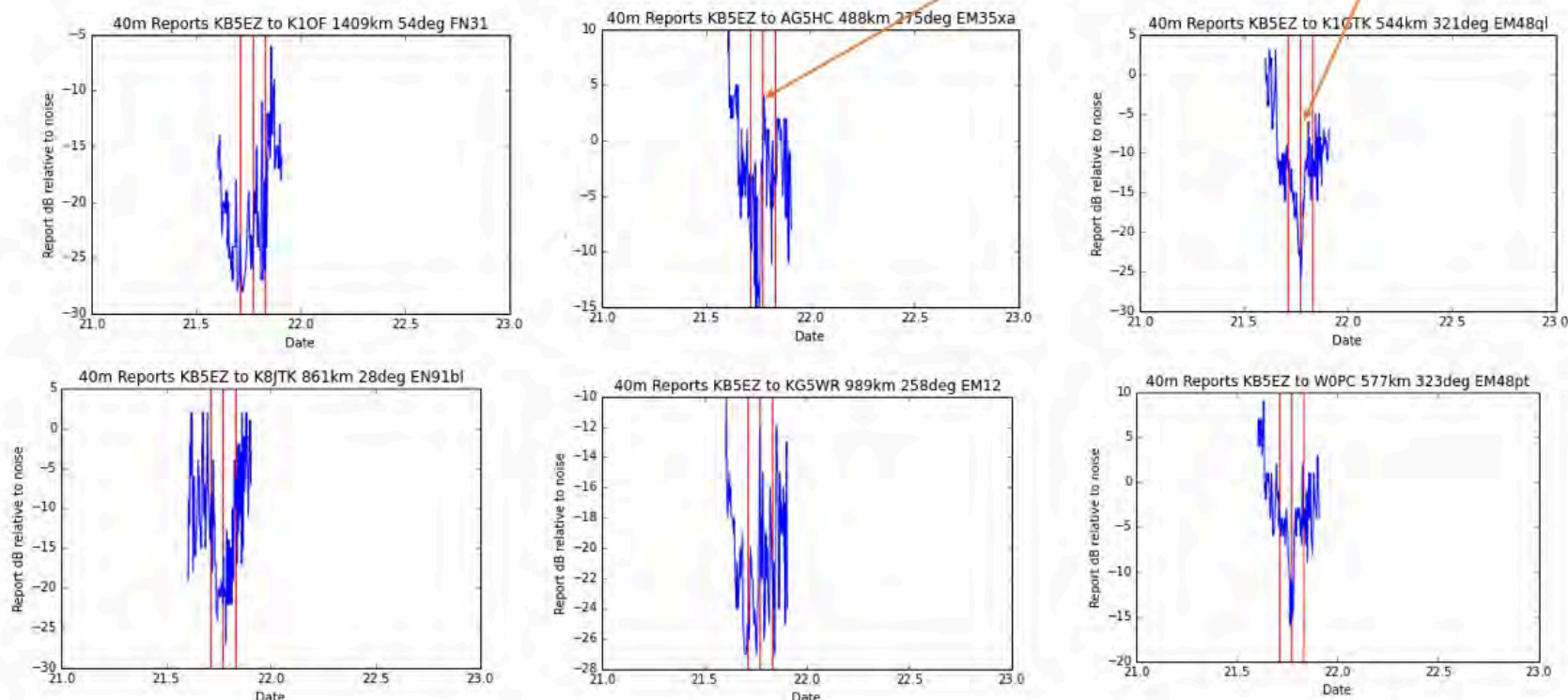


# NN4SA WSPR 40M Transmitter Reception

Figure courtesy Robb Suggs, KB5EZ

## WSPR SNR vs Time 7.0MHz

Attenuation reduction not as dramatic (or non-existent) at higher frequency



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.

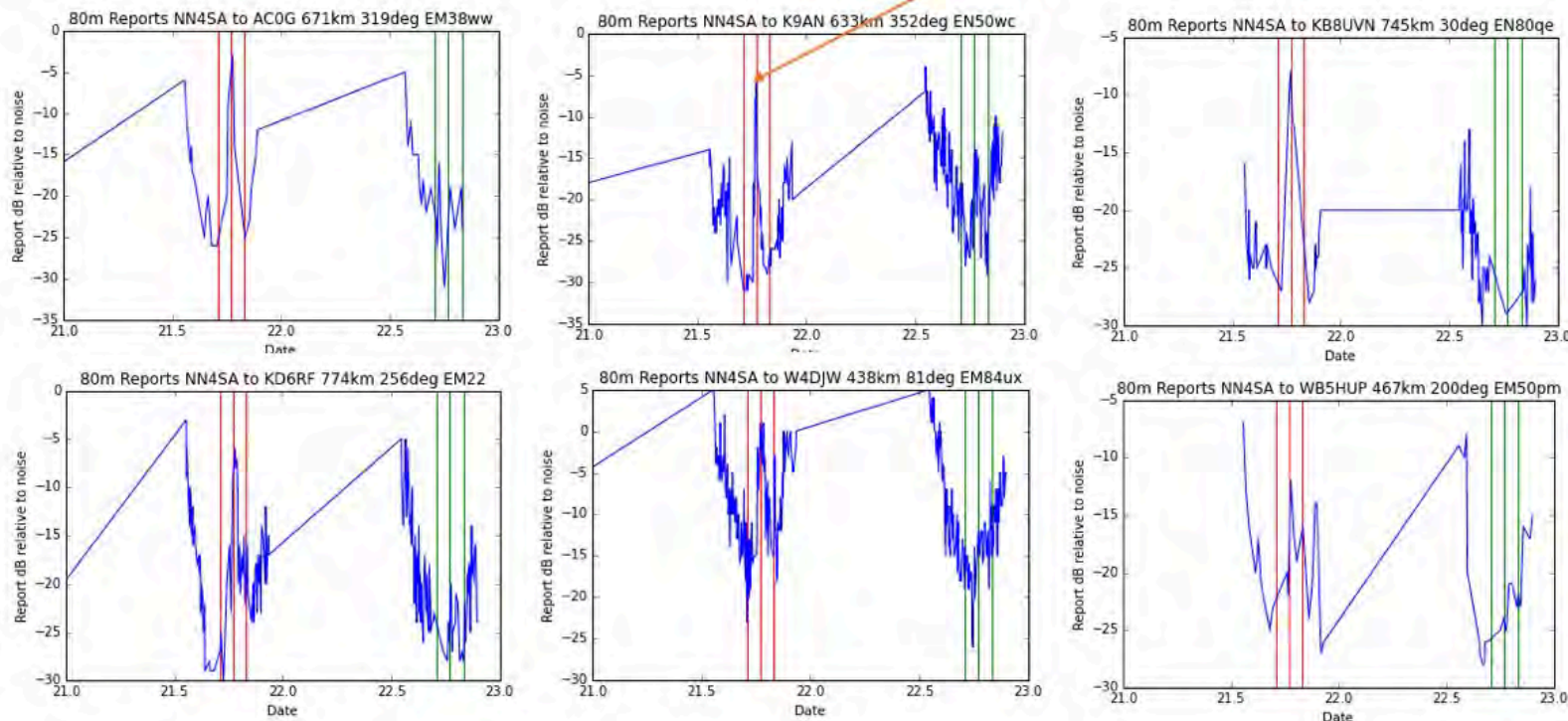


# NN4SA WSPR 80M Transmitter Reception

Figure courtesy Robb Suggs, KB5EZ

## WSPR Signal to Noise Ratio vs Time 3.5 MHz

Reduced D-layer attenuation (from X-rays) at mid-eclipse, stronger signal



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

Reports of SNR on 80M 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.



# 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?

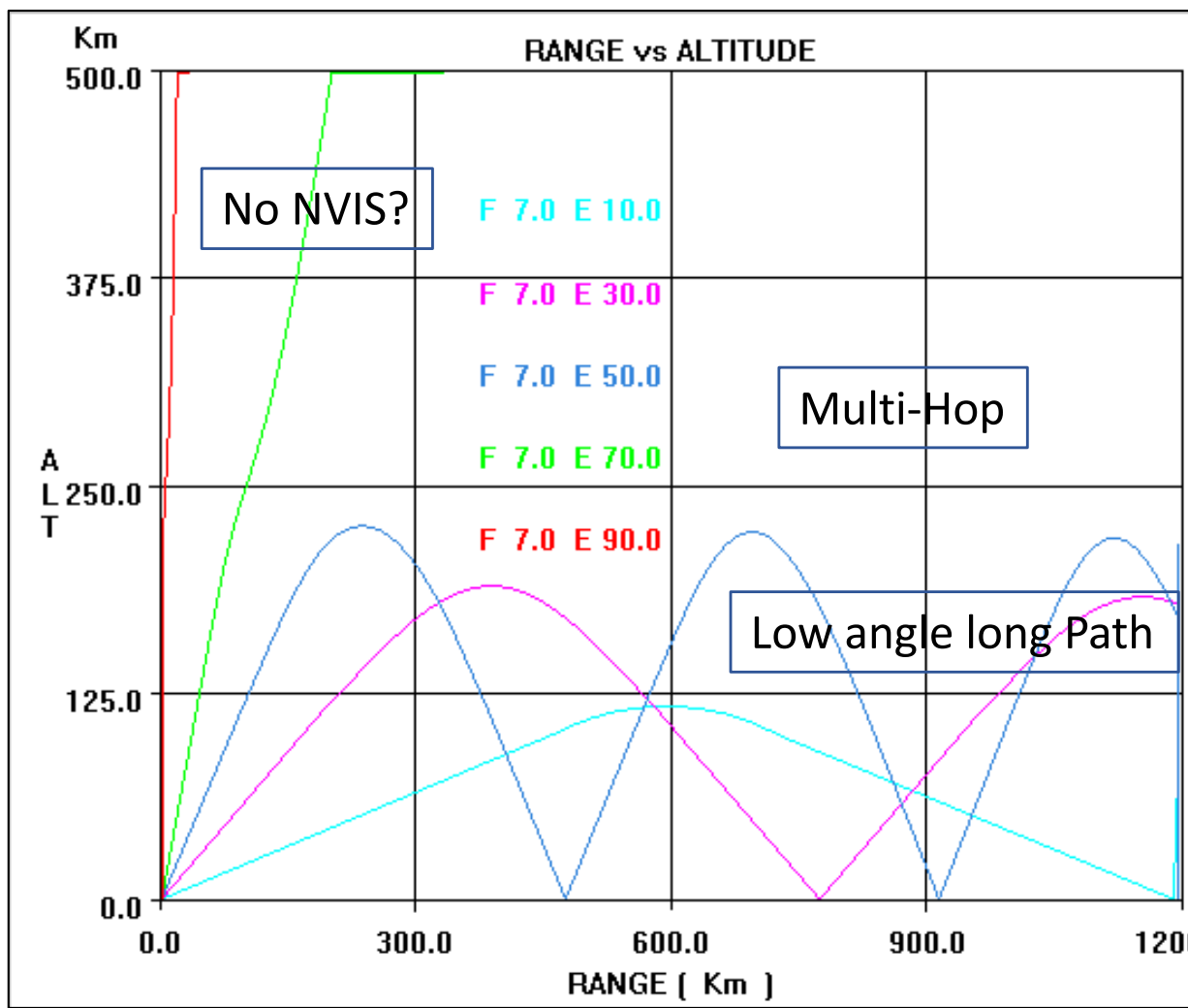
- Line of Sight?
  - Terrain and Distance over the horizon
- Ground Wave?
  - Distance, soil conductivity
- Near Vertical Ionospheric Skywave (NVIS)?
  - $foF2$ , was near 4.0 MHz +/- 0.5 MHz,
  - $hmF2$ , height of F2 layer peak, ranging 196-244 km.
- PIM says no

# 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

$f_oF2 \sim 3.5 - 4.5$  MHz,  
 $h_mF2 \sim 196-244$  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

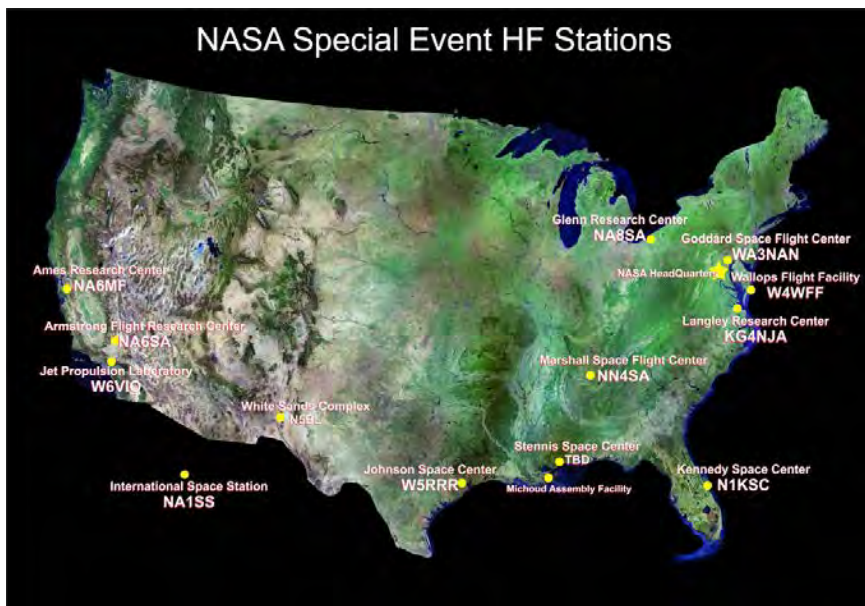
- Improving ionospheric radio science capabilities:
  - Install RBN CW Skimmer and WSPR receivers at MSFC/NSSTC
  - Upgrade SDR hardware, software, site location\*
  - Continue to engage Hams, students and citizen scientists
- Preparing for the next Big Eclipse opportunity
  - Chile, 2019 (?)
  - Mexico/USA 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 45<sup>th</sup> anniversary – 11-19 December 2017, beginning of event
- NASA founded 60<sup>th</sup> anniversary (act signed by President Eisenhower) – 29 July 1958
- ISS First Element Launch 20<sup>th</sup> anniversary – 20 November 1998
- ISS Node 1 Launch 20<sup>th</sup> anniversary – 4 December 1998
- 50<sup>th</sup> anniversary of Apollo 8 – launch 21 December 1968
- Apollo 8 – splashdown 27 December 1968, end of event



## QSL Card and Certificate



<https://nasaontheair.wordpress.com>