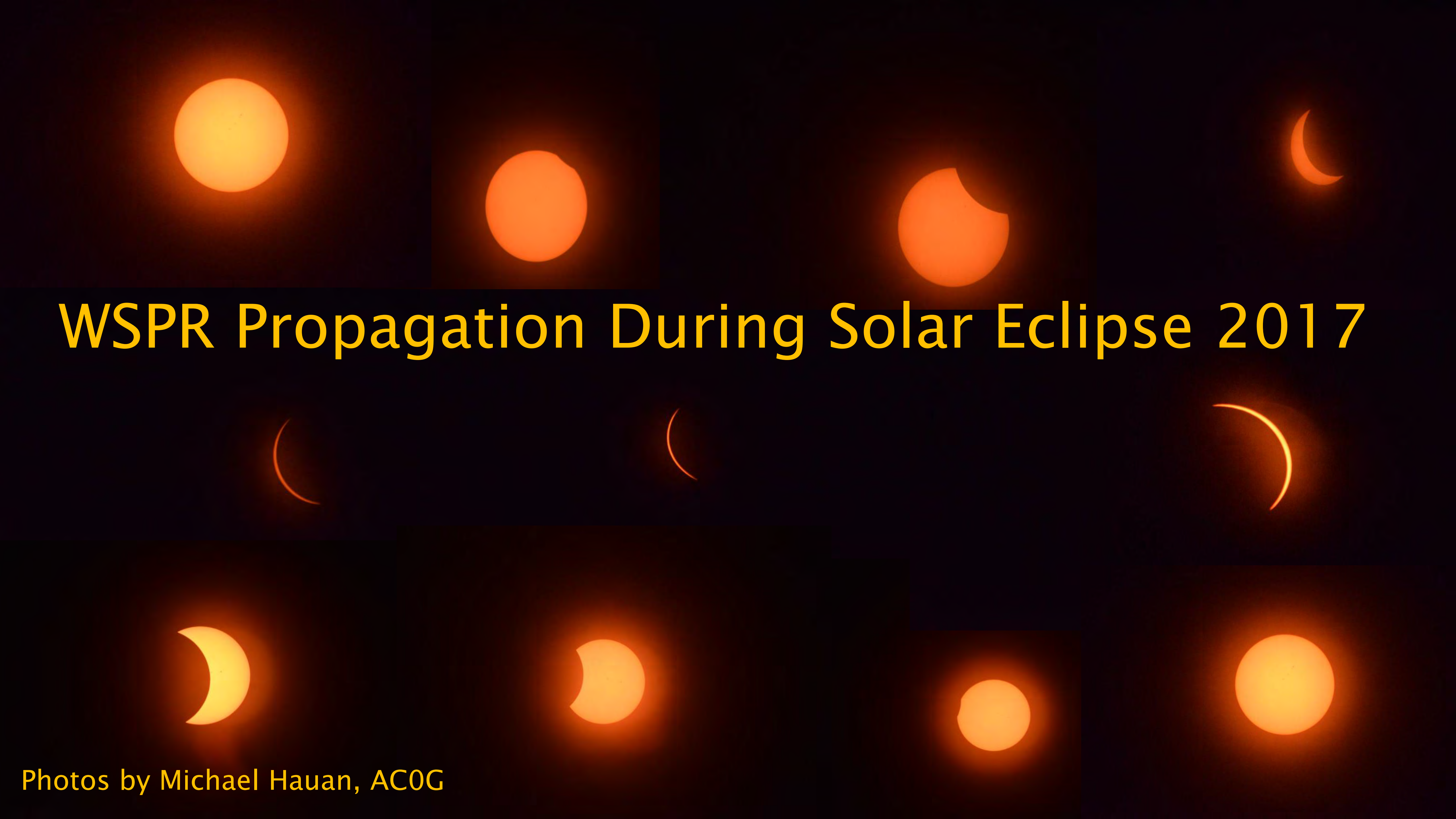

WSPR Propagation During Solar Eclipse 2017
Photos by Michael Hauan, AC0G

COLLABORATION AMONG CURIOUS RADIO AMATEURS

MICHAEL HAUAN, AC0G

ROBERT WILHITE, AJ5E

JAY TAFT, K1EHZ

DAVID BENZEL, KD6RF

BILL HARRISON, KK4XO

DAVID WHITE, NV0O

MIKE MILLER, W1EAA

JIM POLL, WB5WPA

CONARD MURRAY, WS4S

See *CQ* Magazine, December 2017 and February 2018 for more details.

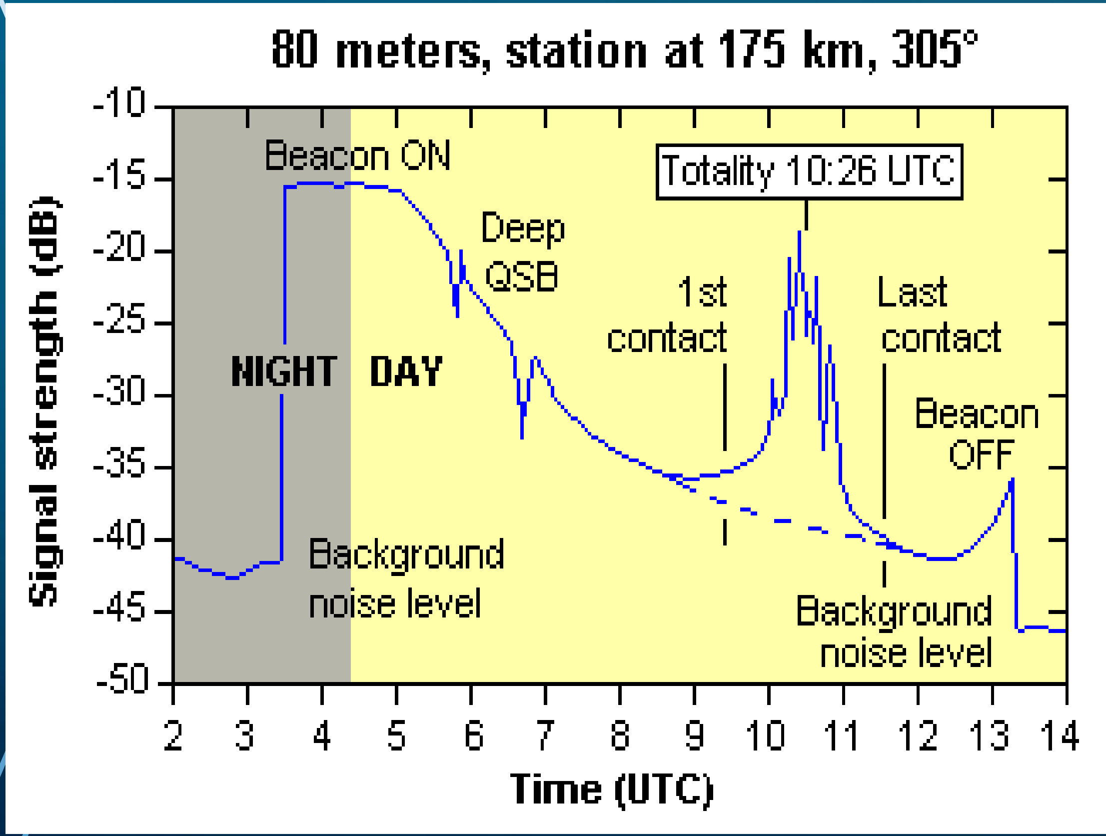
ECLIPSE STUDIES

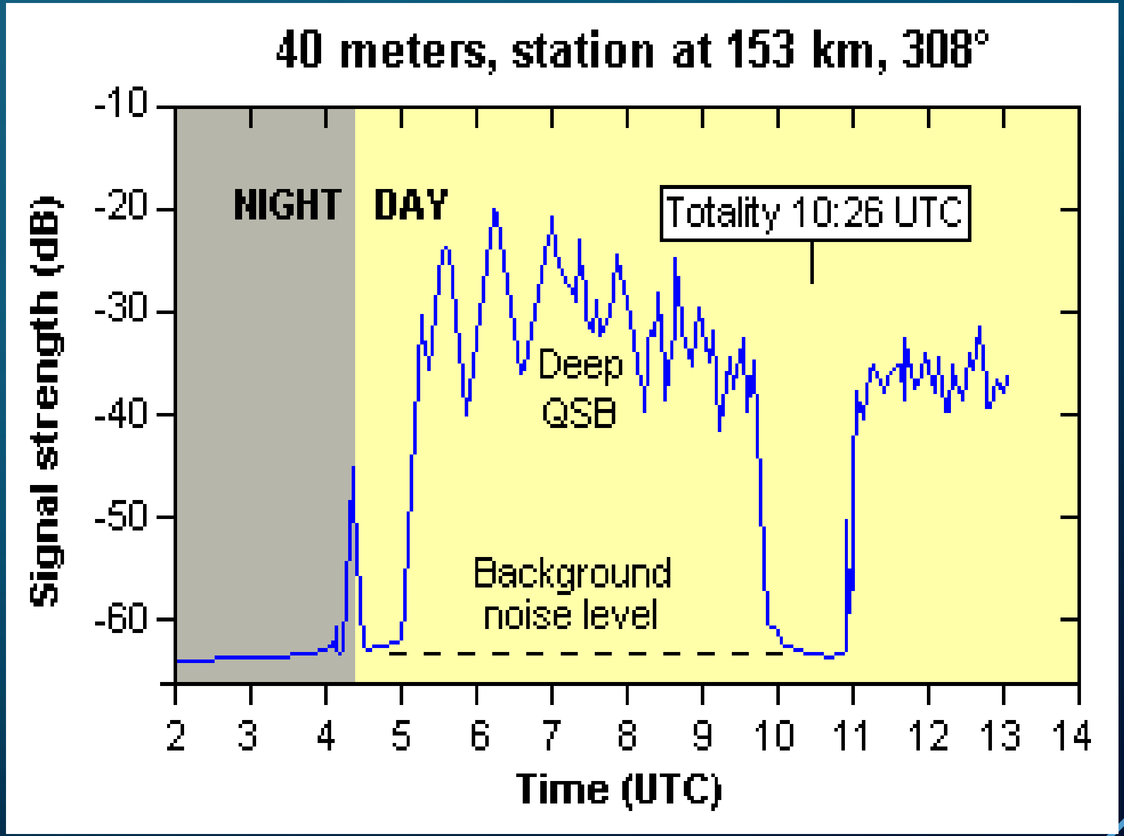
- A recent review article cited data from 44 eclipse studies.
- First recorded eclipse data were temperature measurements by an anonymous observer in Boston in 1834.
- Modern observations still include meteorology plus
  - Ionosonde – radar measures ionosphere electron density profile
  - Critical frequencies for D, E and F layers of the ionosphere
  - Total electron content
  - Radio propagation
  - Radio frequency noise
  - GPS satellite time discrepancies (gain ~45 μsec/d due to relativity)

QUESTIONS WE WERE CURIOUS ABOUT

- What amateur bands might be affected by propagation changes?
- Where should we focus our attention because equipment is limited and diverse across our stations?
- How much baseline data would we need before and after the eclipse to identify propagation changes?
- Are there ground wave and sky wave effects that could mask eclipse effects?
- How strong and long-lasting might eclipse effects be?
- How is propagation affected along and across the axis of totality?
- How large is the affected area?
- What propagation mechanisms might be related to an eclipse?

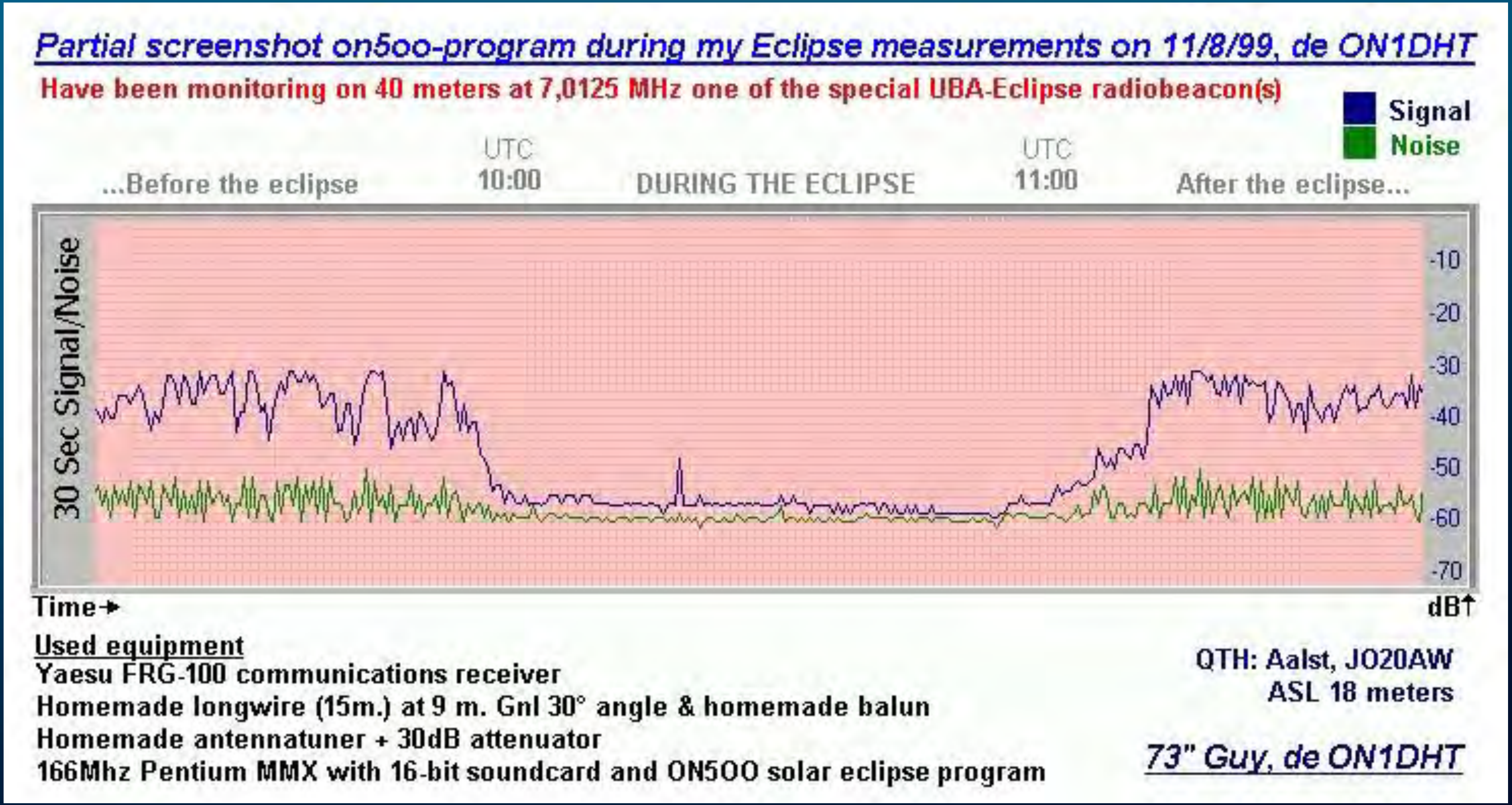
600W BEACONS HEARD DURING 1999 UK / EUROPE ECLIPSE



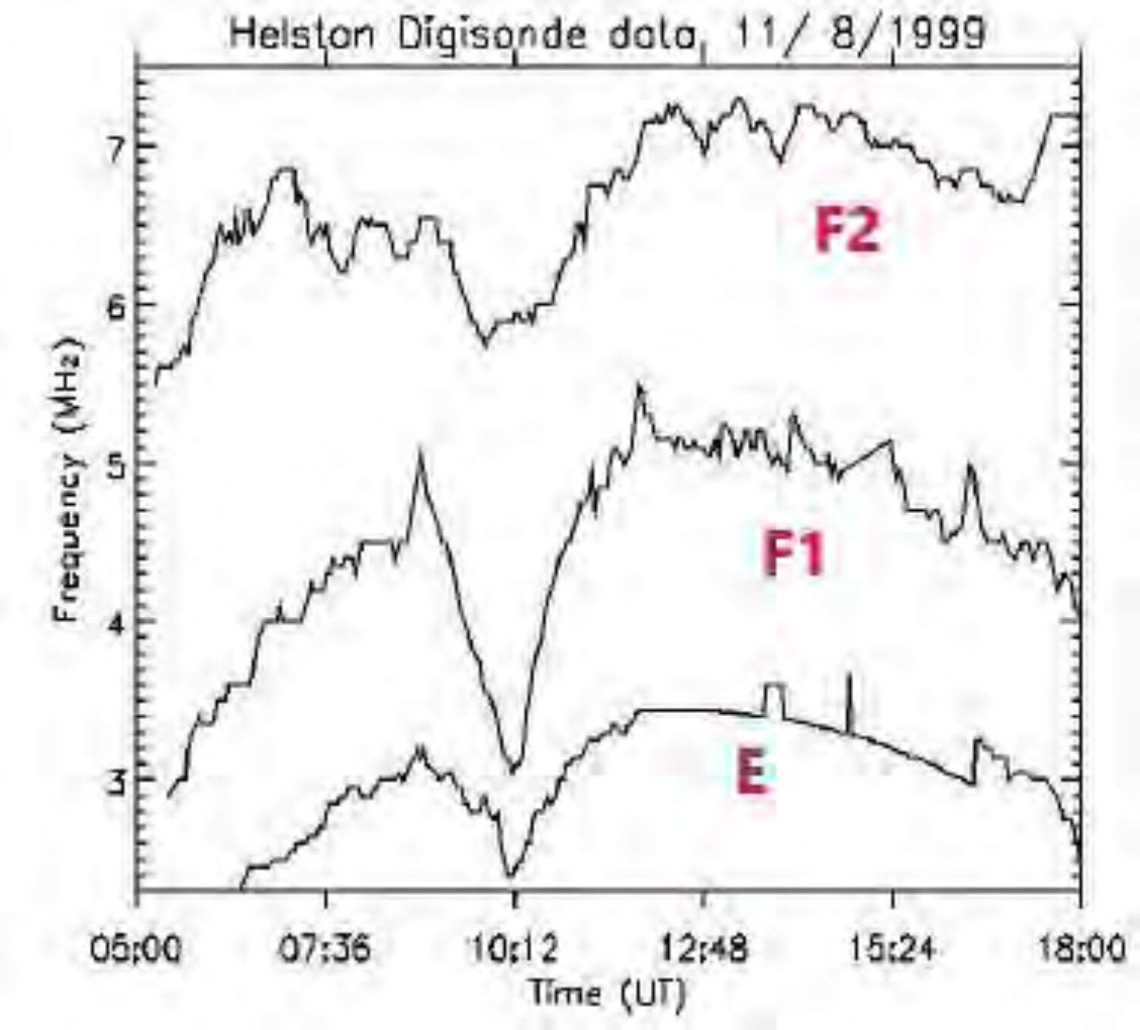


HTTP://WWW.ASTROSURF.COM/LUXORION/QSL-ECLIPSE-D-LAYER.HTM

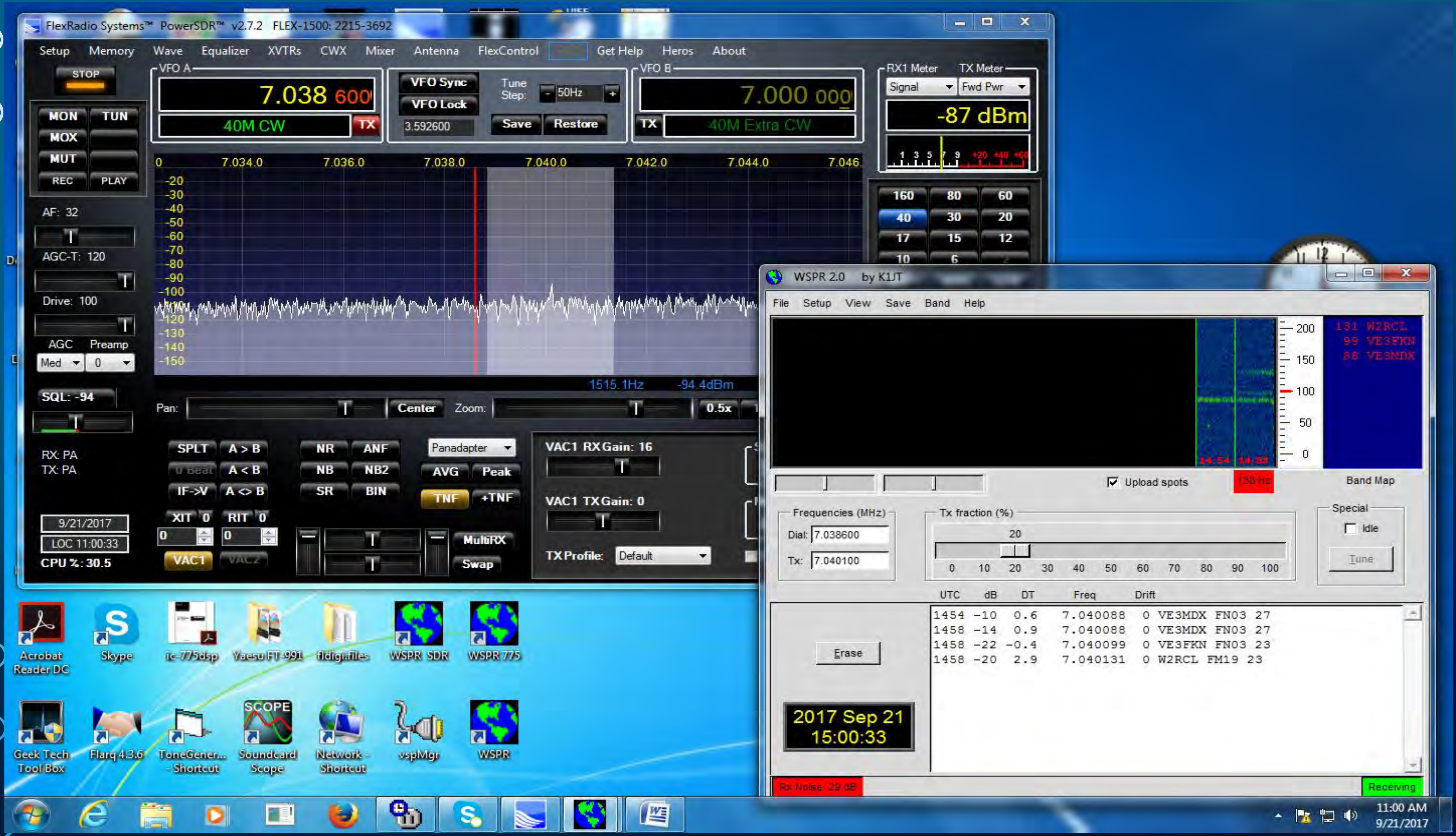
ON1DHT SIGNAL AND NOISE DECREASE FOR 600W BEACON ON 40M DURING 1999 UK / EUROPE ECLIPSE



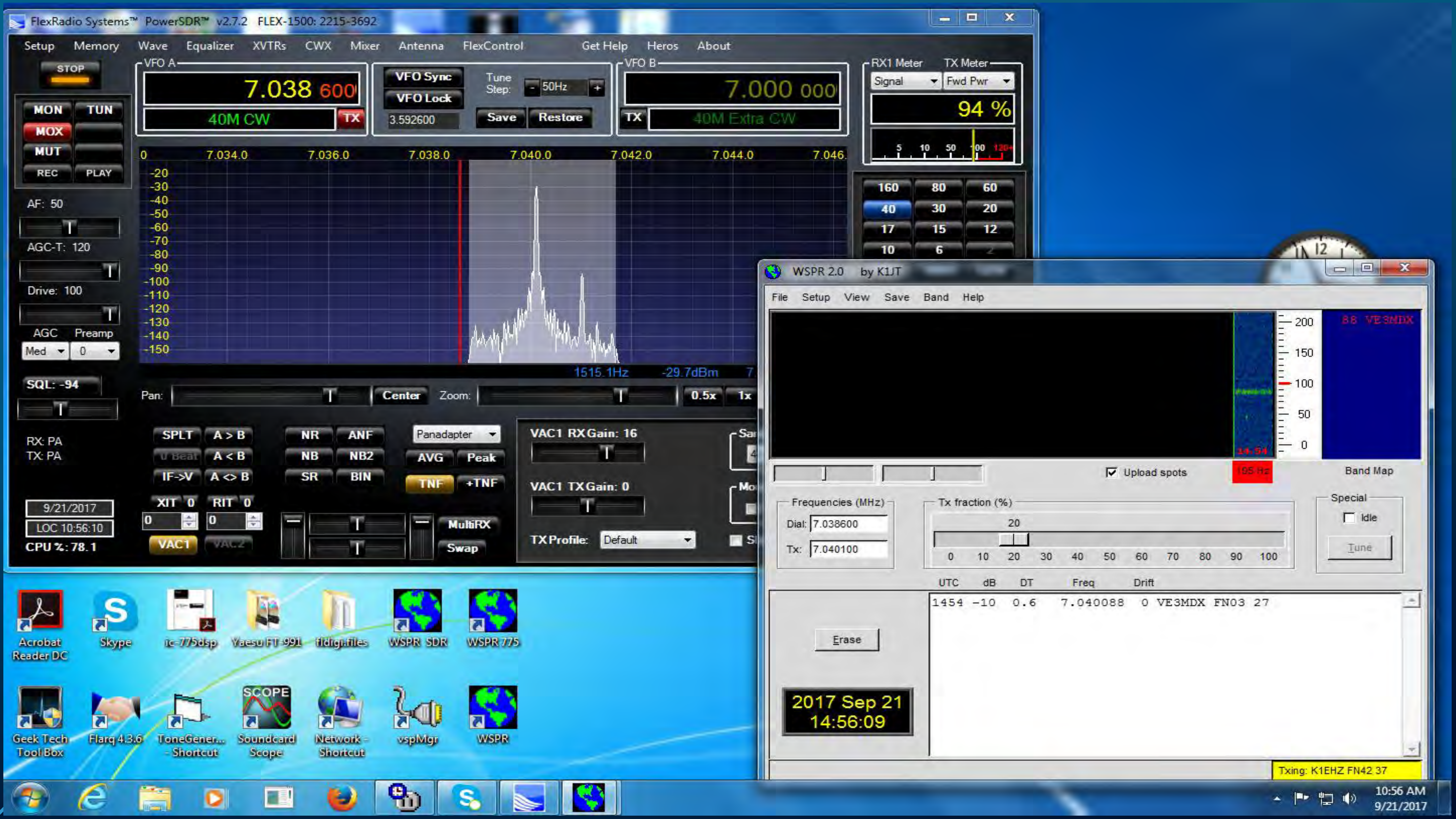
DIGISONDE DATA FOR 1999 UK / EUROPE ECLIPSE
CRITICAL FREQUENCY DROP IN ALL LAYERS
COURTESY OF DR. RUTH BAMFORD, RUTHERFORD APPLETON LABORATORY, UK



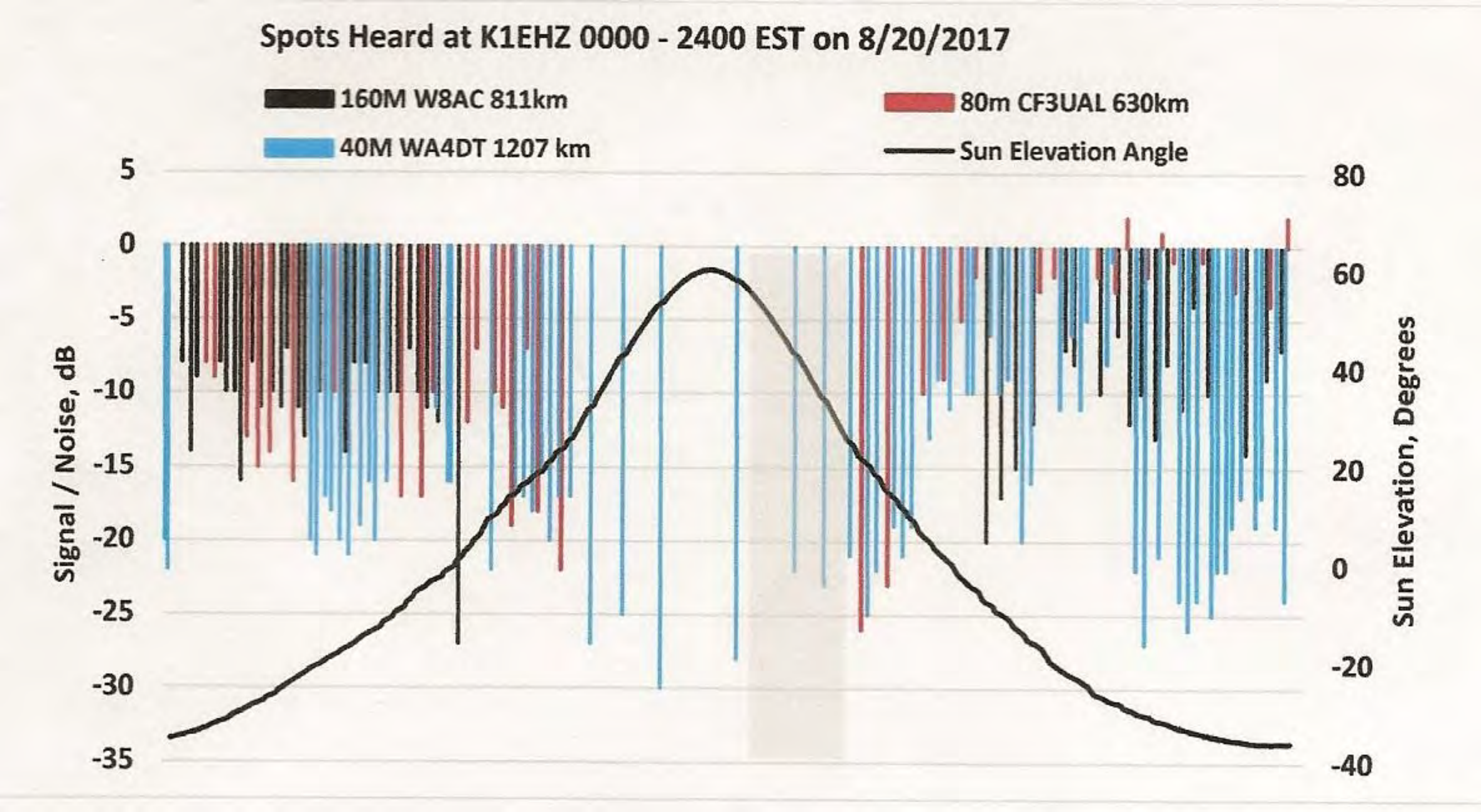
FLEX 1500 & WSPR RECEIVING ON 40M



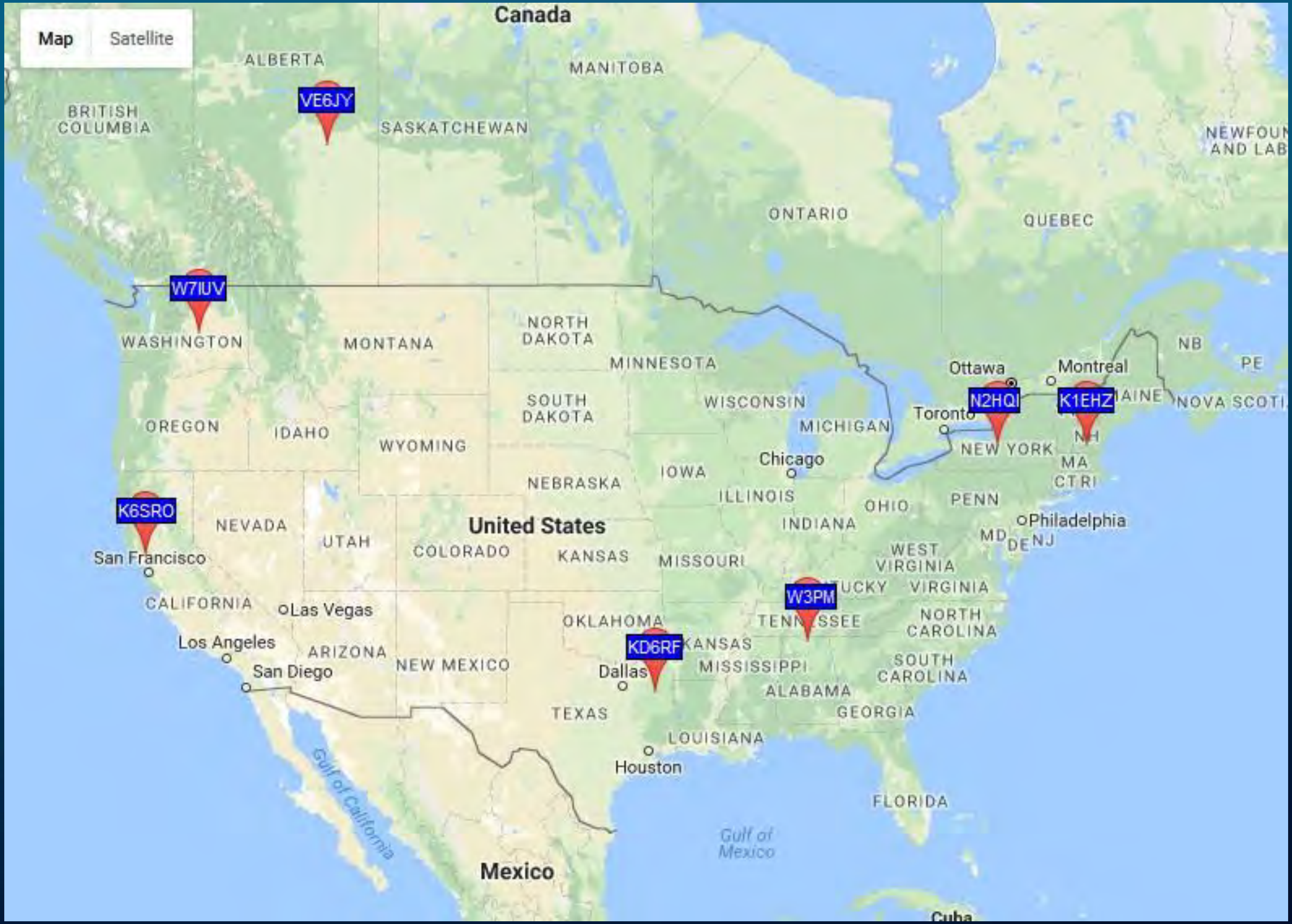
FLEX 1500 & WSPR TRANSMITTING ON 40M



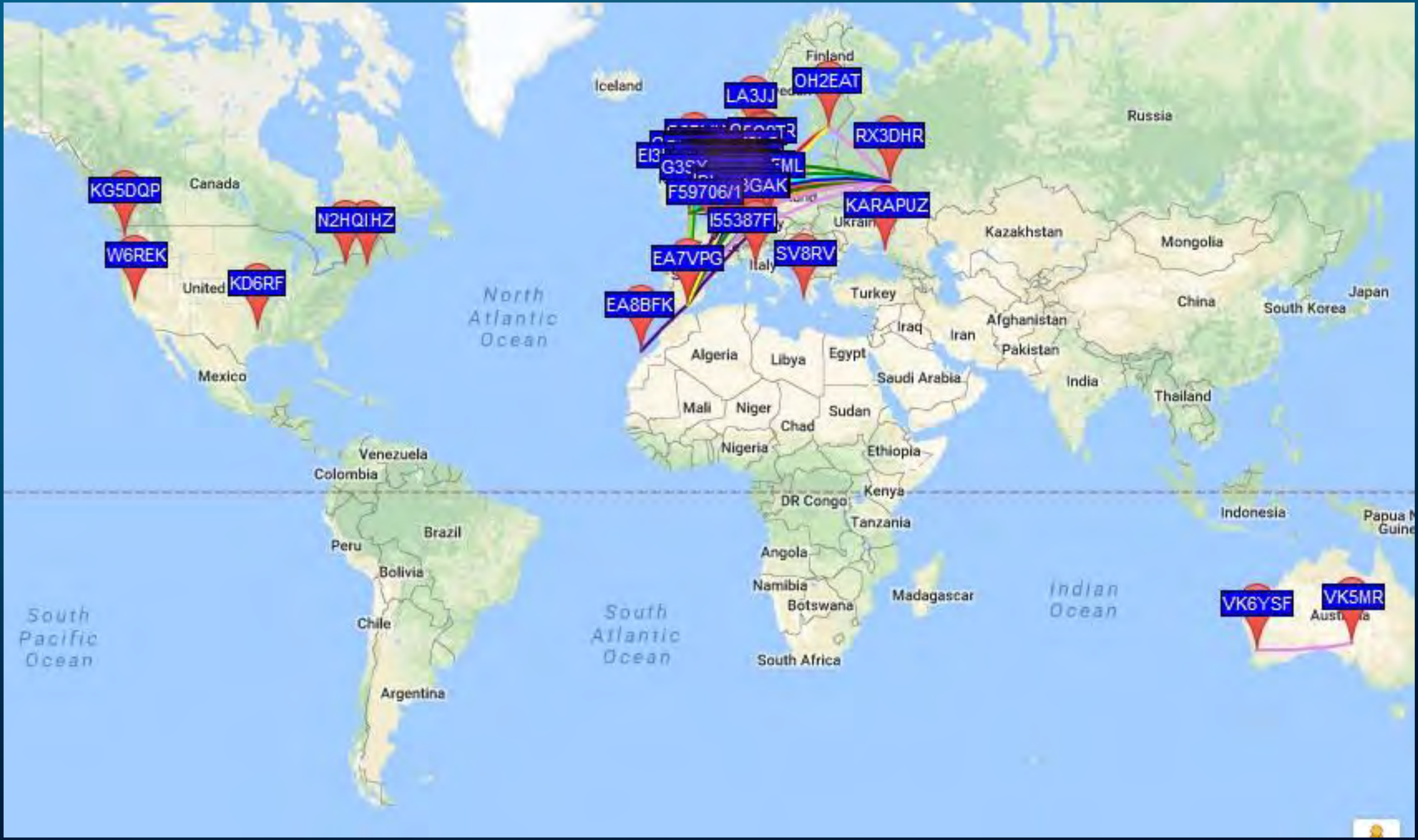
WHAT BANDS MIGHT BE AFFECTED BY ECLIPSE PROPAGATION CHANGES?



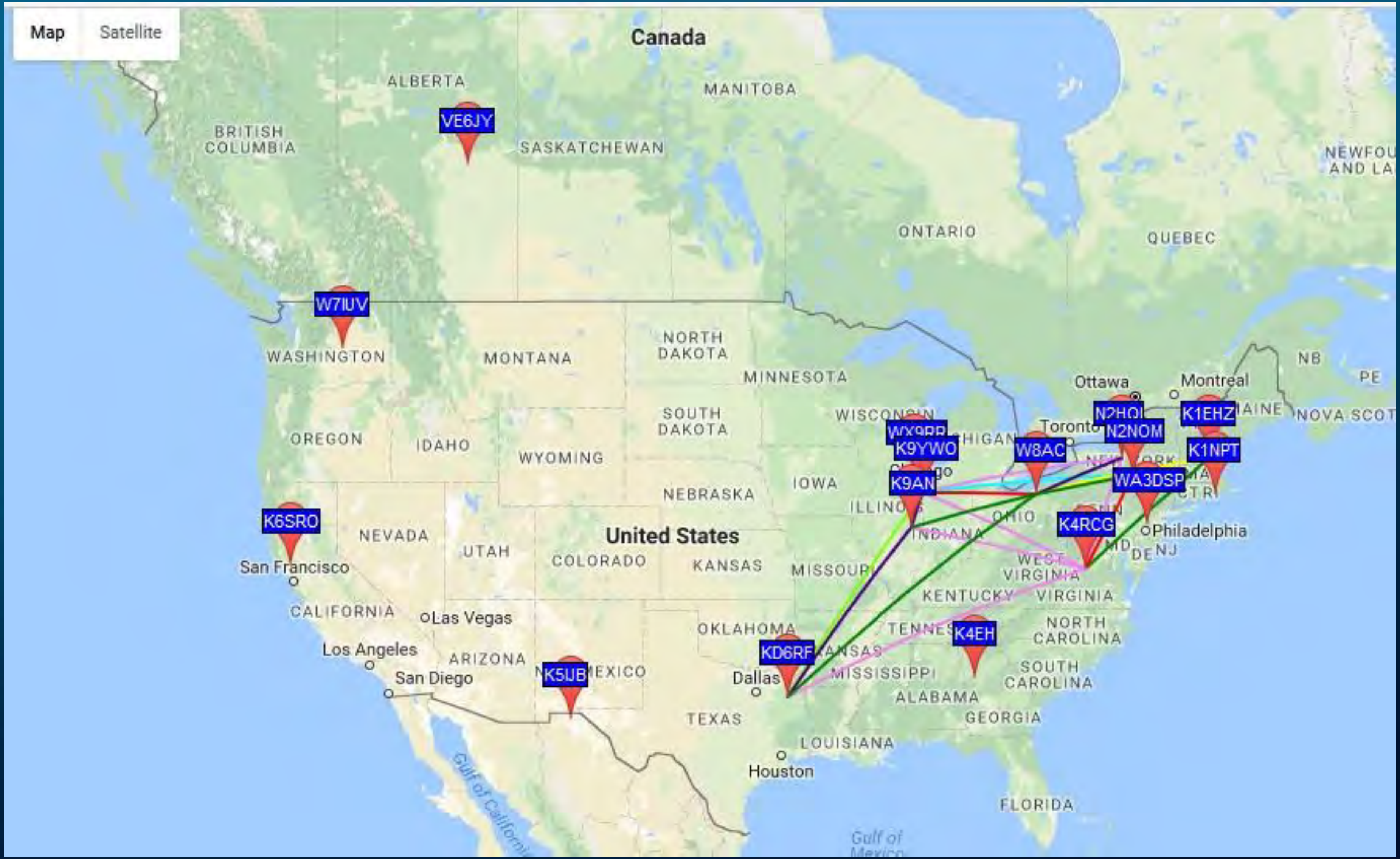
WSPR MAP OF 160M IN DAYLIGHT



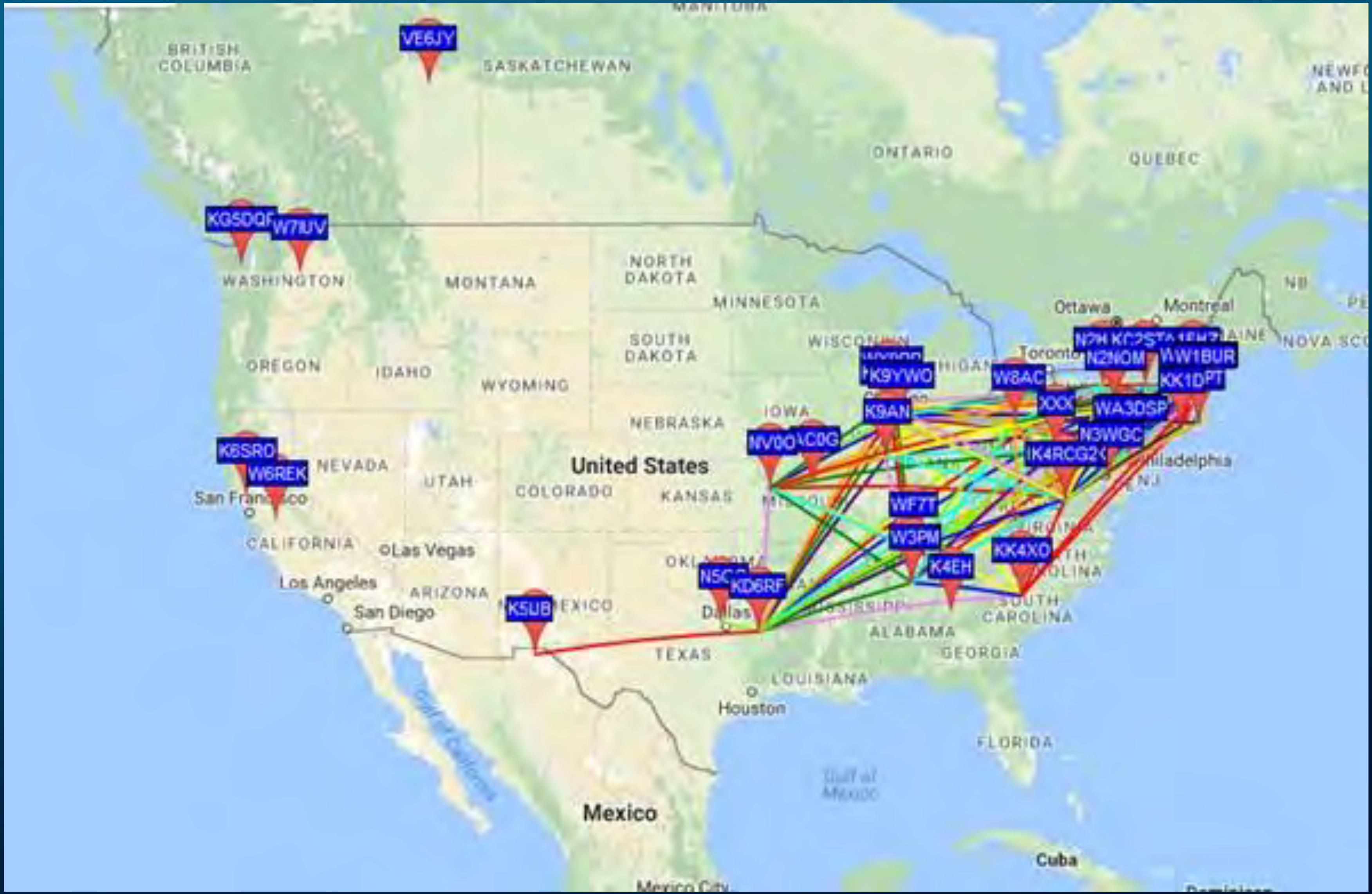
WSPR MAP 160M 1645 EDT 9/17/2017



WSPR MAP OF 160M AT 20:40 EDT

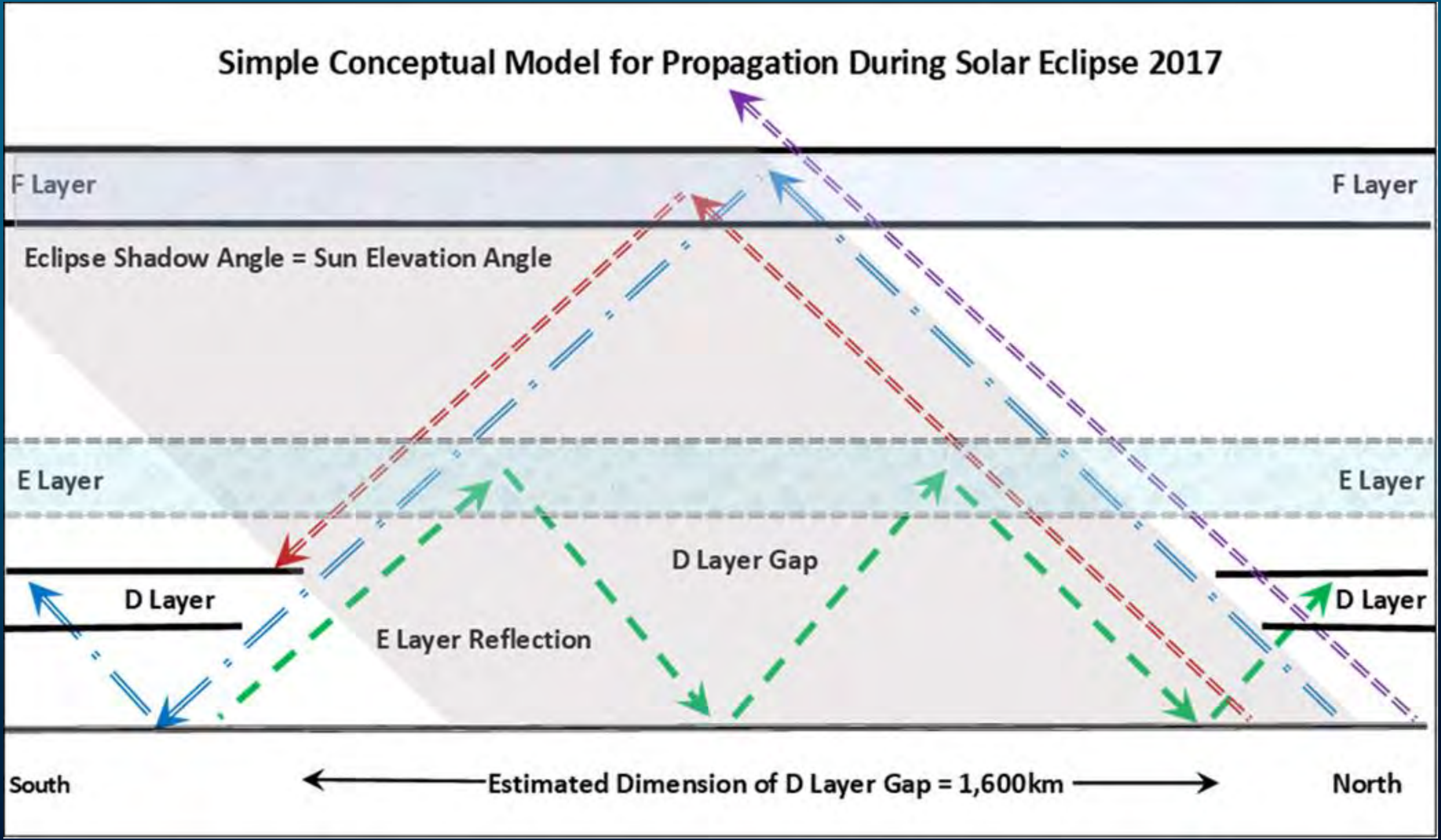


WSPR MAP OF 160M AT 22:30 EDT



OVER-SIMPLIFIED ECLIPSE PROPAGATION MODEL

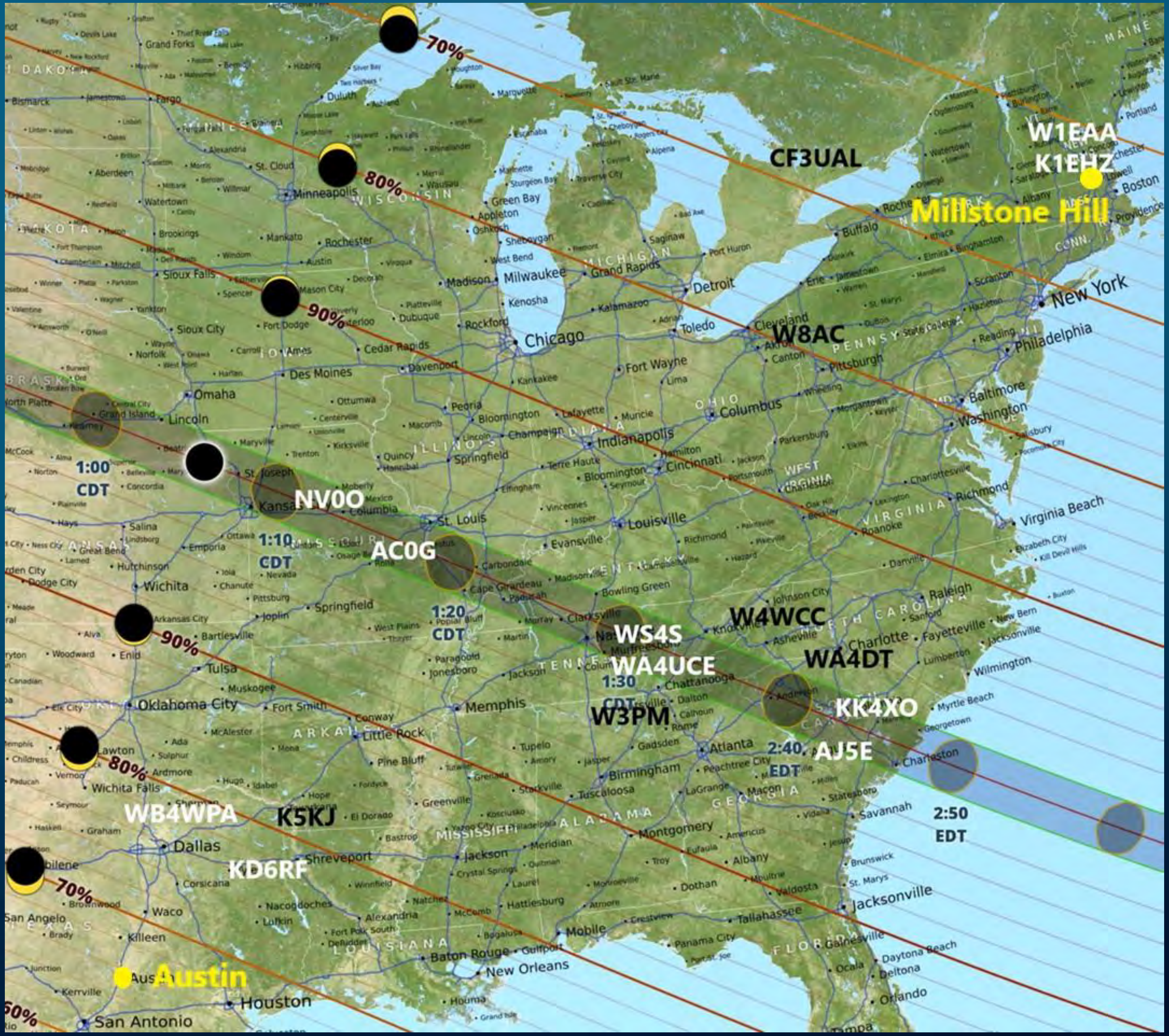
BASED ON OUR DATA THE D LAYER GAP IS ABOUT 1,600KM IN DIAMETER
UMBRA (SHADOW) TRAVELS 2,400KM/HR, OR 1.5 GAP DIAMETERS/HR



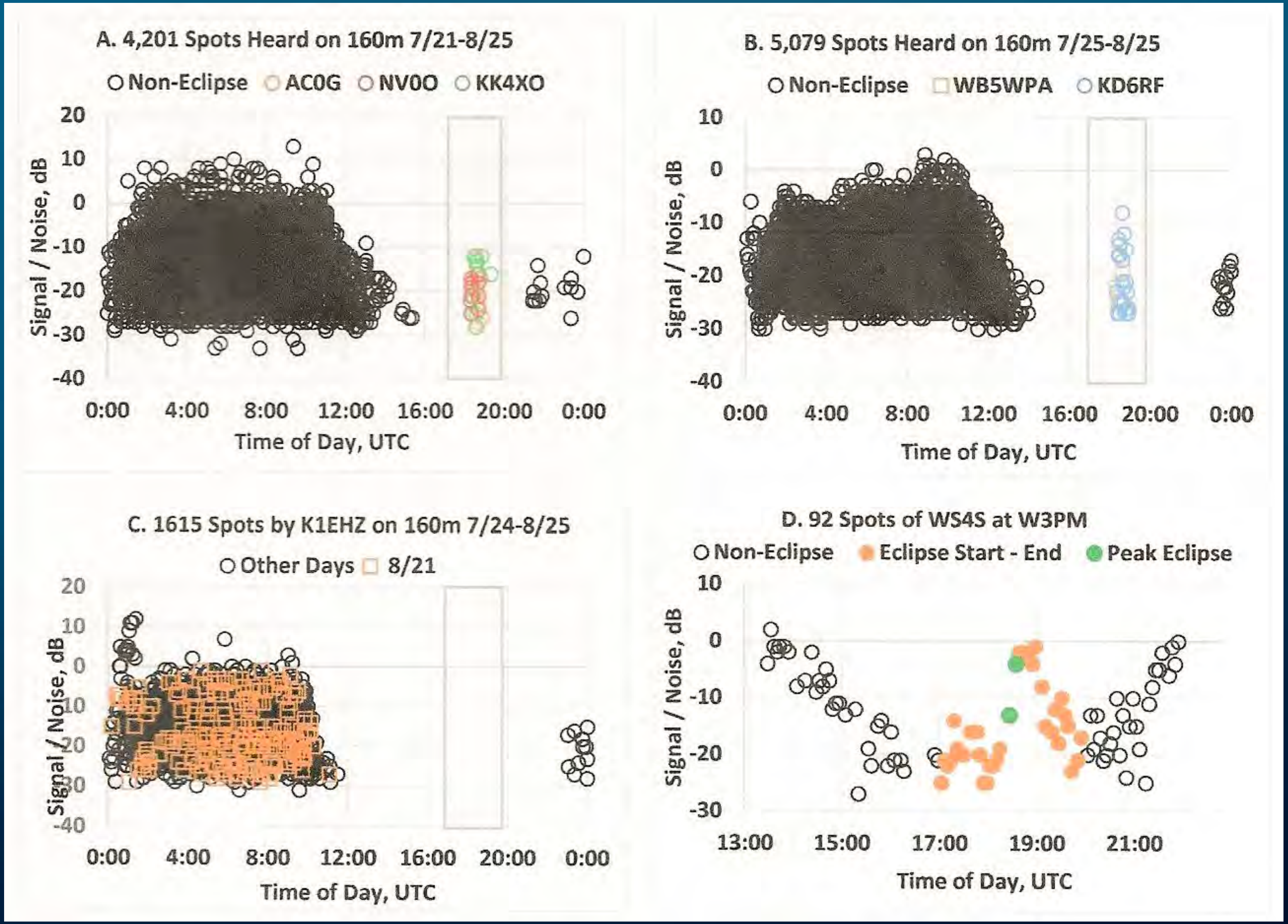
CONVENTIONAL PROPAGATION MODEL

- The previous slides illustrate conventional understanding of light – dark propagation changes.
- D layer forms during daylight and absorbs RF on the low bands.
- During darkness the solar energy, mostly UV, required to maintain the D layer is gone and the D layer dissipates.
- Low band propagation enhanced by reflection from E and F layers during darkness.
- *Therefore, eclipse darkening should enhance low band propagation.*

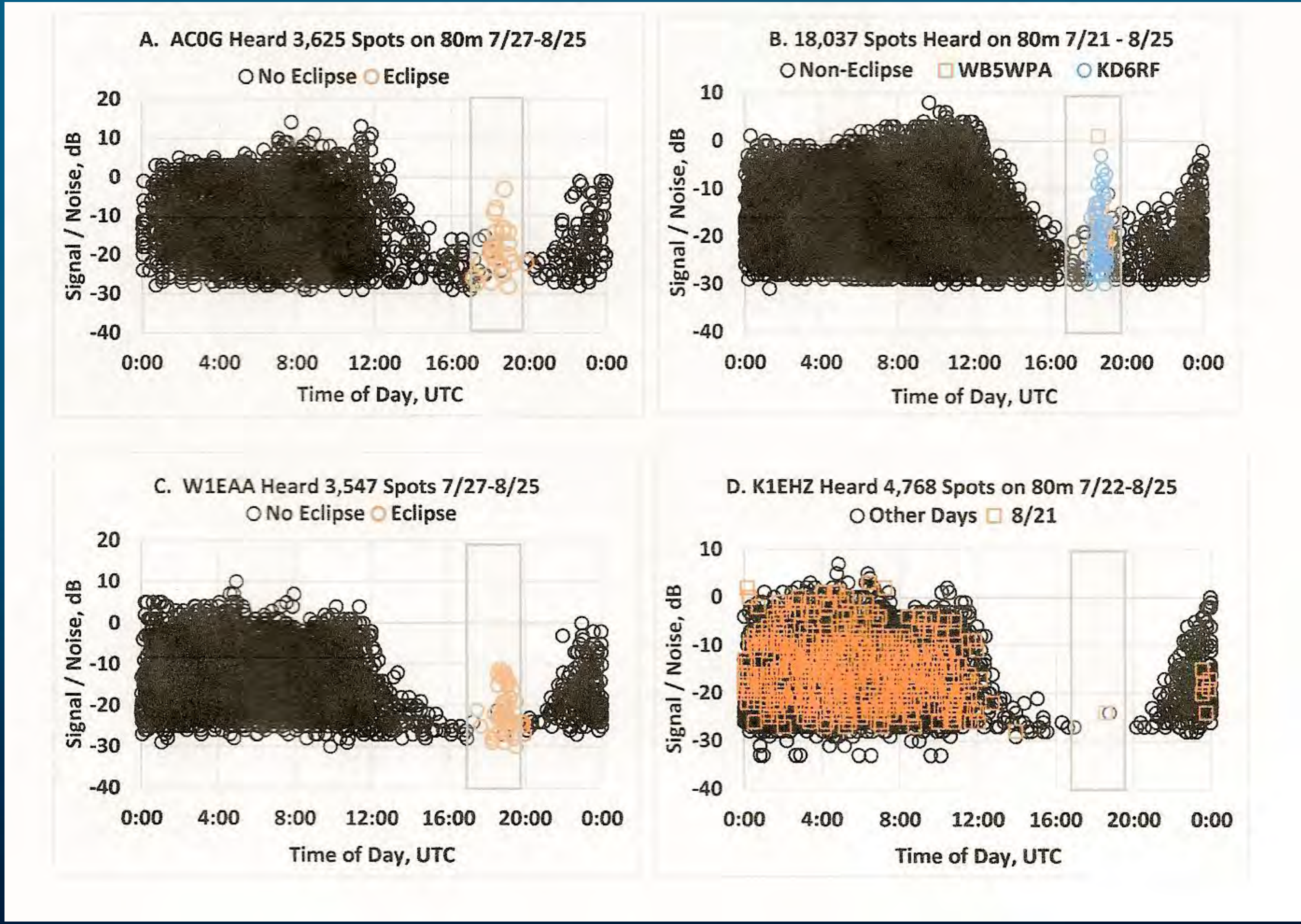
RELATIVE LOCATIONS OF STATIONS



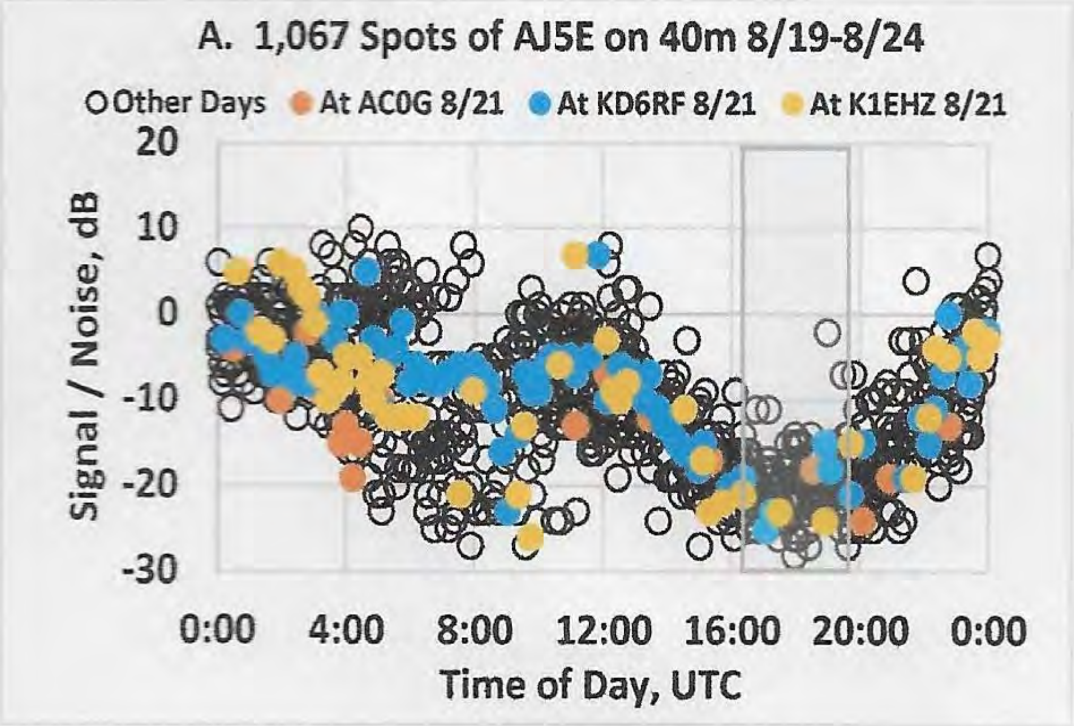
160M RESULTS. A. ALONG THE AXIS B. PERIPHERAL SOUTH C. PERIPHERAL NORTH D. TIME DETAIL

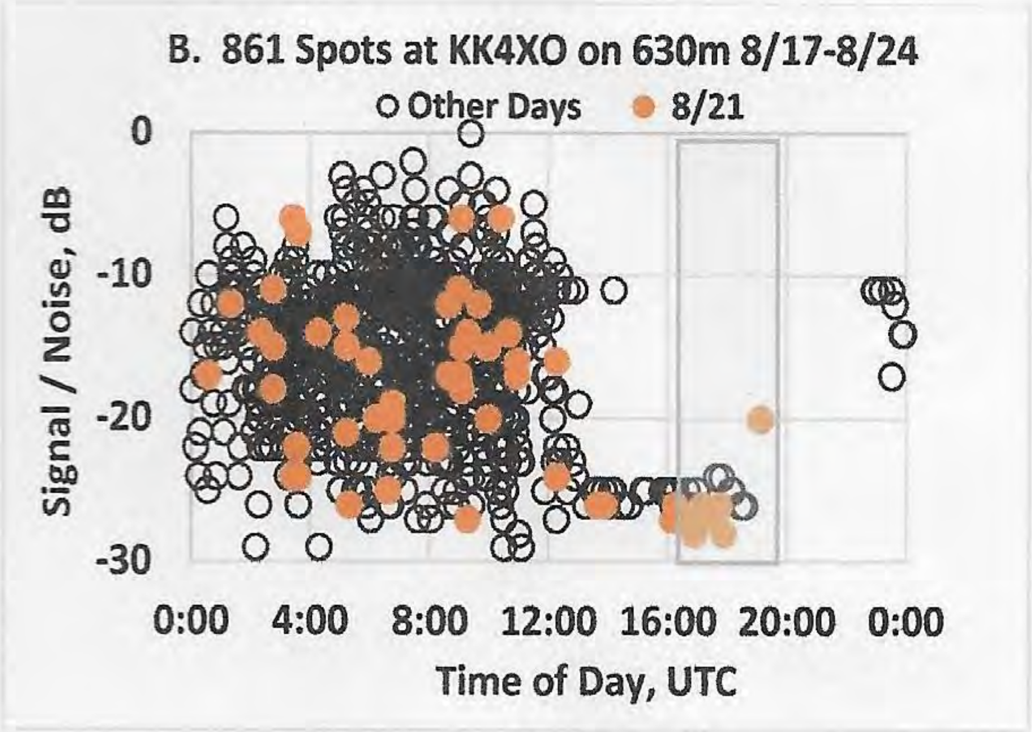


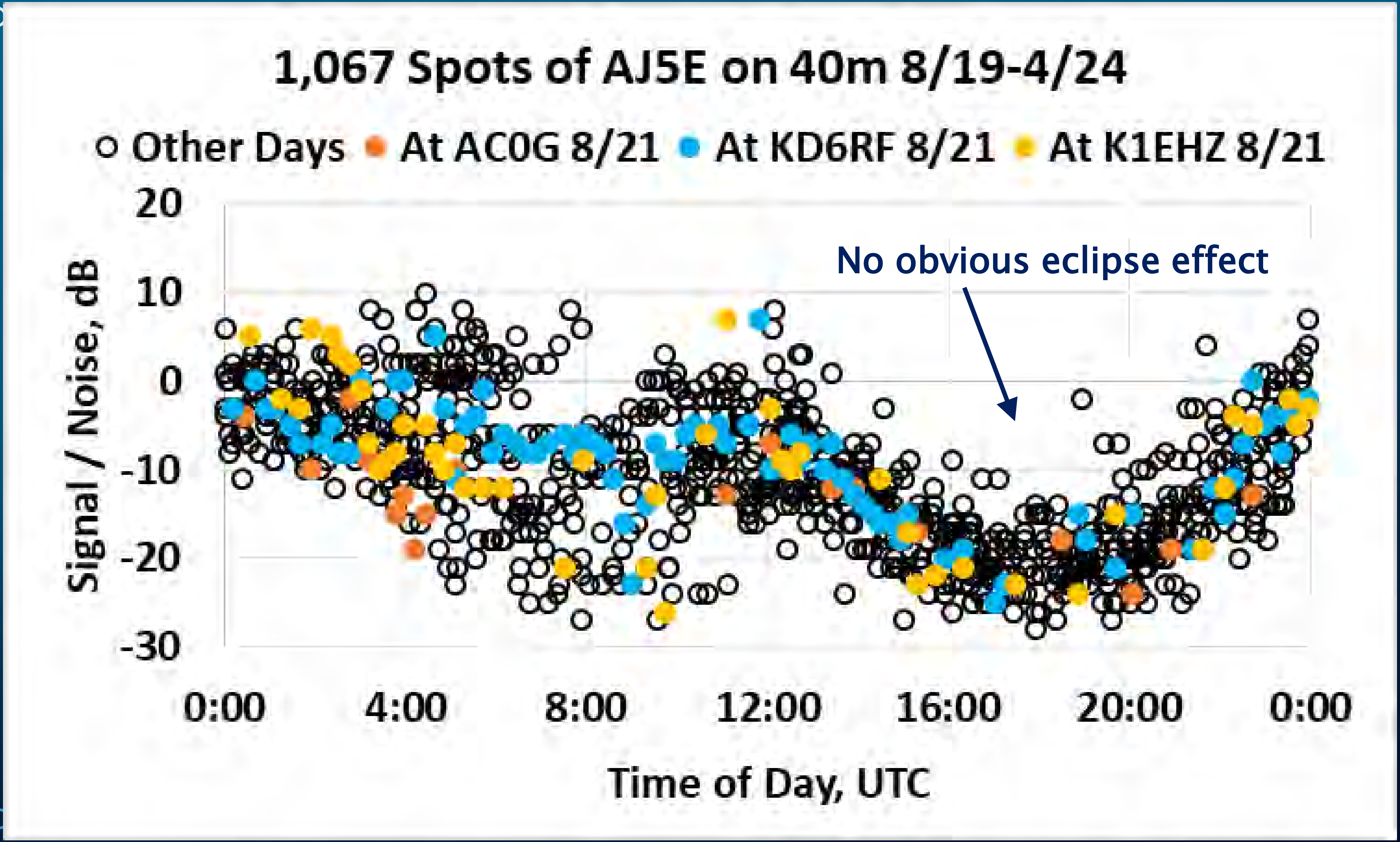
80M RESULTS. A. ALONG THE AXIS B. PERIPHERAL SOUTH C. PERIPHERAL NORTH D. PERIPHERAL NORTH

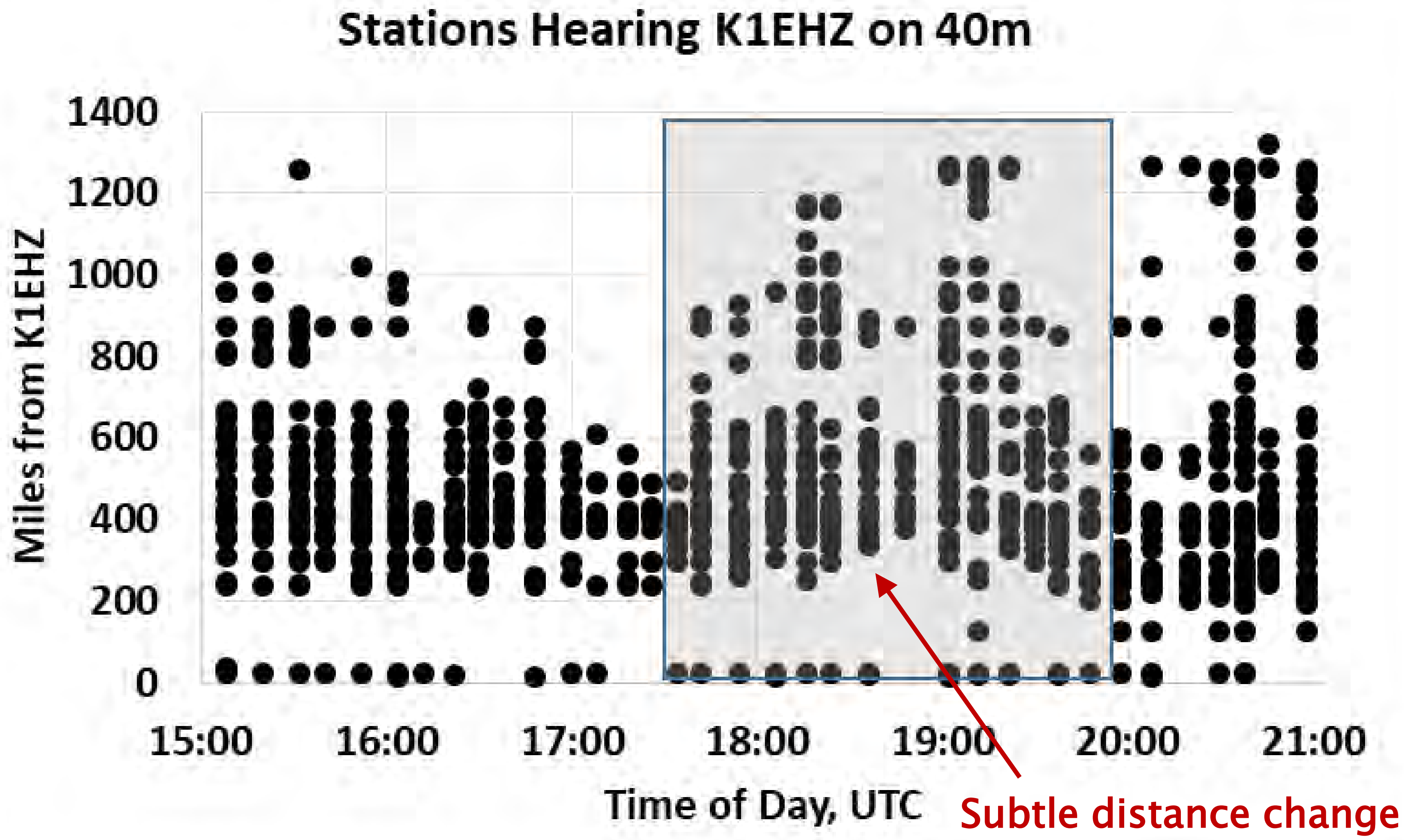


40M AND 630M


A. 1,067 Spots of AJ5E on 40m 8/19-8/24
Other Days
At AC0G 8/21
At KD6RF 8/21
At K1EHZ 8/21
Signal / Noise, dB
20
10
0
-10
-20
-30
0:00
4:00
8:00
12:00
16:00
20:00
0:00
Time of Day, UTC

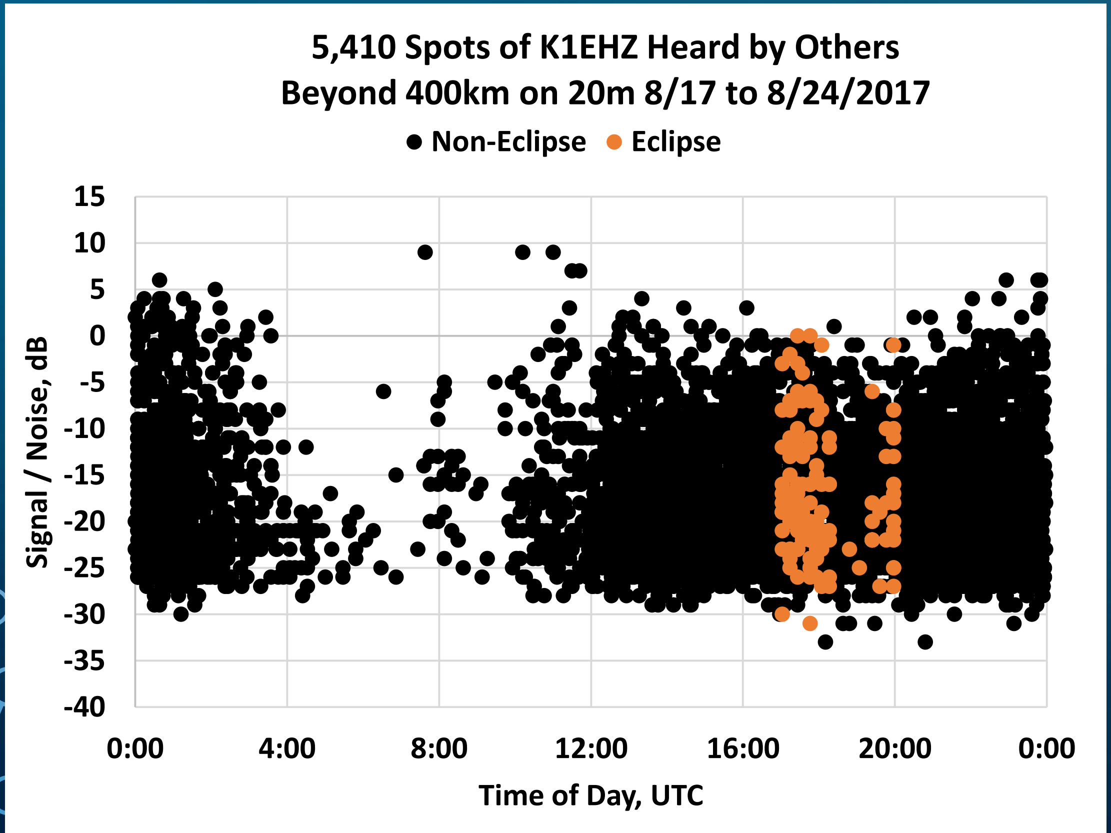

B. 861 Spots at KK4XO on 630m 8/17-8/24
Other Days
8/21
Signal / Noise, dB
0
-10
-20
-30
0:00
4:00
8:00
12:00
16:00
20:00
0:00
Time of Day, UTC

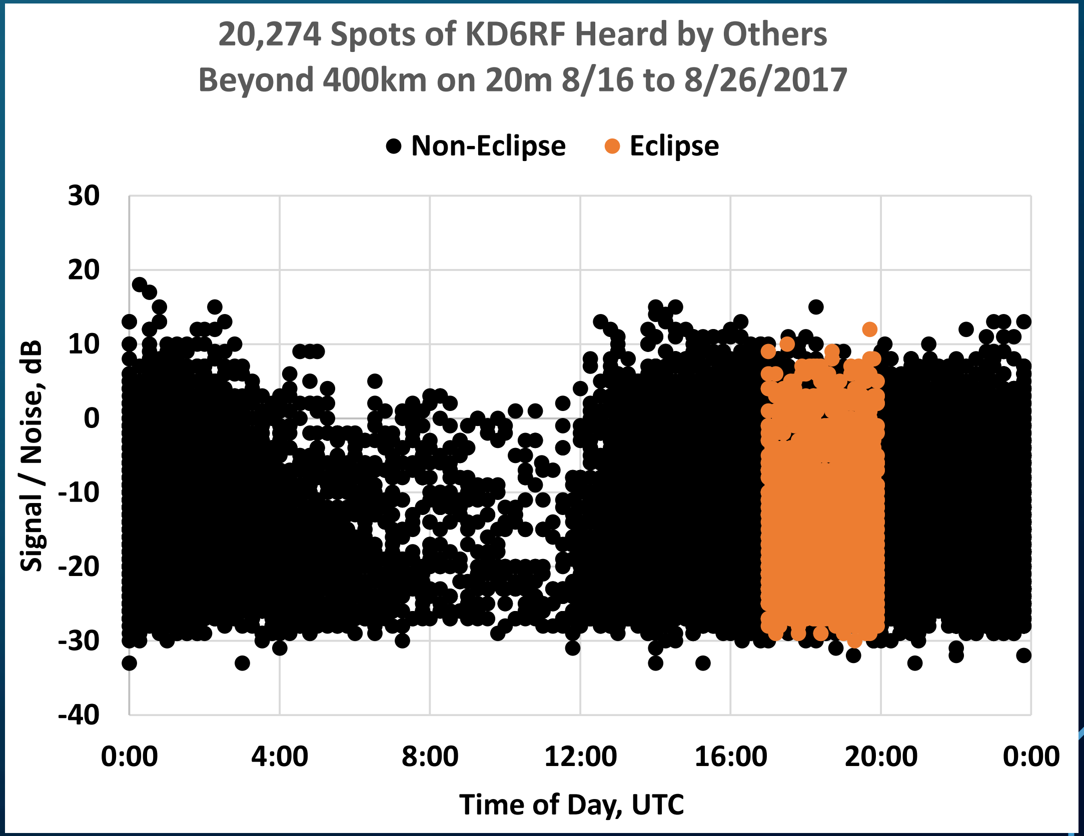

1,067 Spots of AJ5E on 40m 8/19-4/24
Other Days
At AC0G 8/21
At KD6RF 8/21
At K1EHZ 8/21
No obvious eclipse effect
Signal / Noise, dB
20
10
0
-10
-20
-30
0:00
4:00
8:00
12:00
16:00
20:00
0:00
Time of Day, UTC

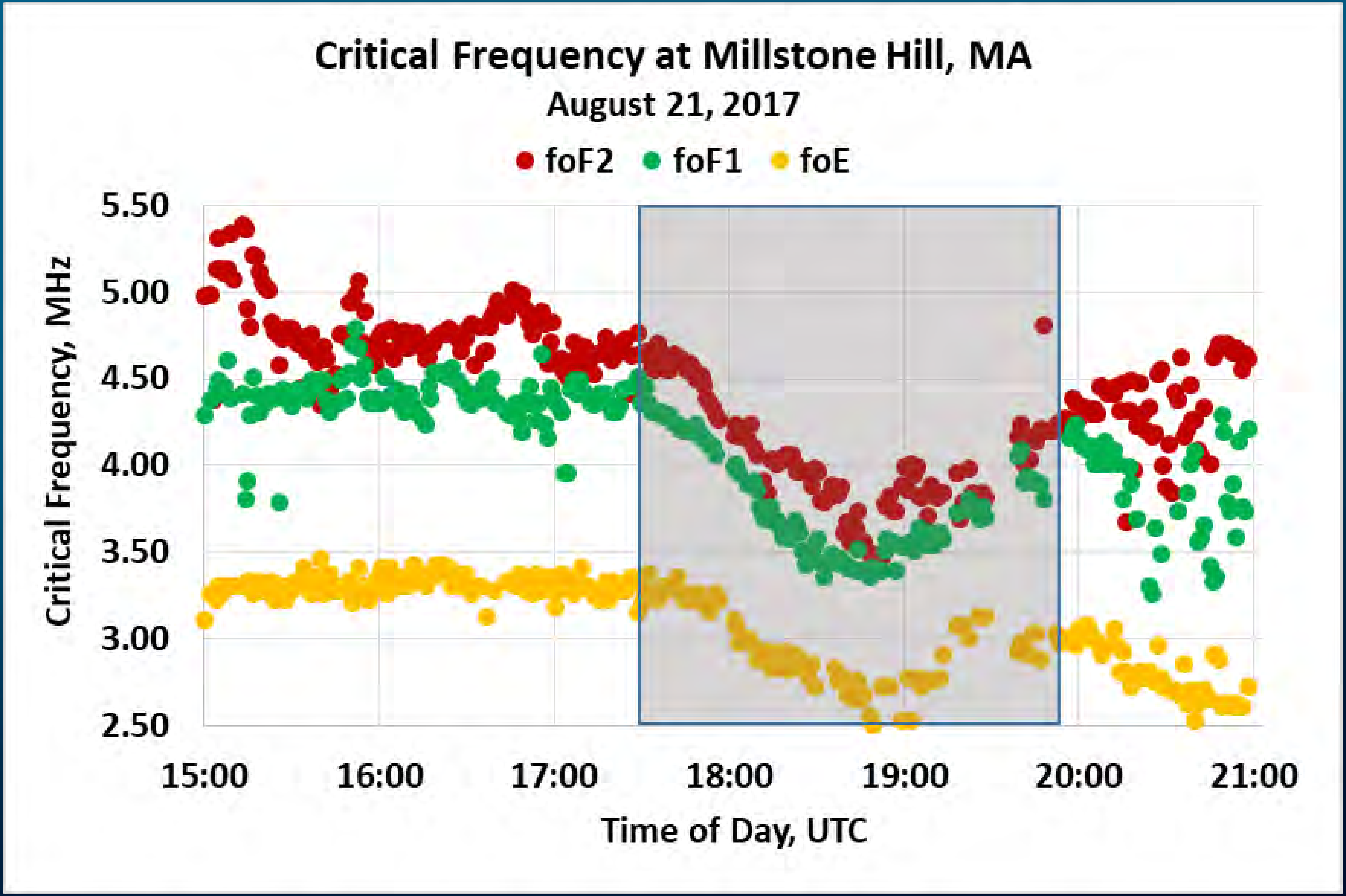

Stations Hearing K1EHZ on 40m
Miles from K1EHZ
1400
1200
1000
800
600
400
200
0
15:00
16:00
17:00
18:00
19:00
20:00
21:00
Time of Day, UTC
Subtle distance change

ECLIPSE EFFECTS ON 20M

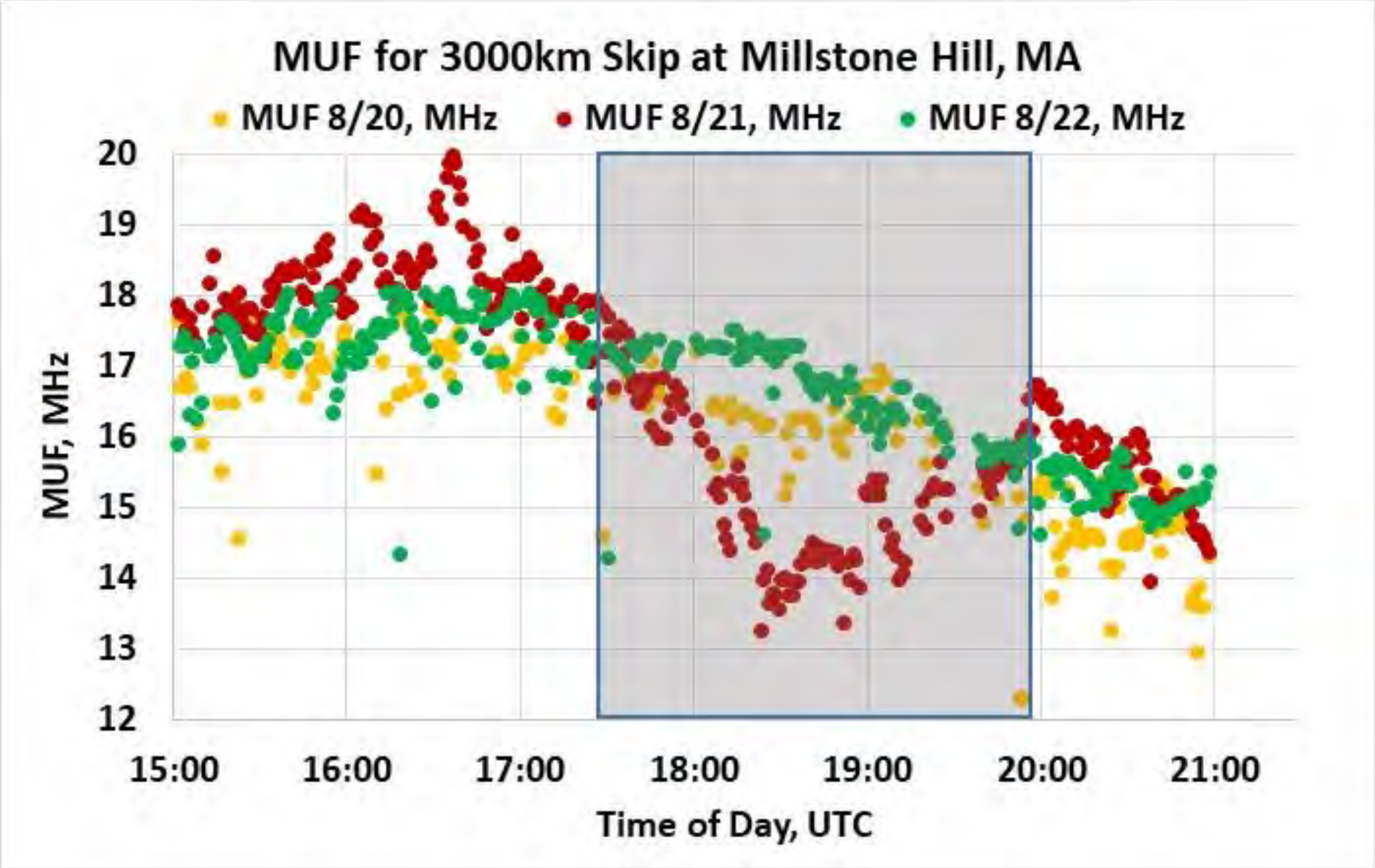
Apparent gap at K1EHZ but not at KD6RF during eclipse

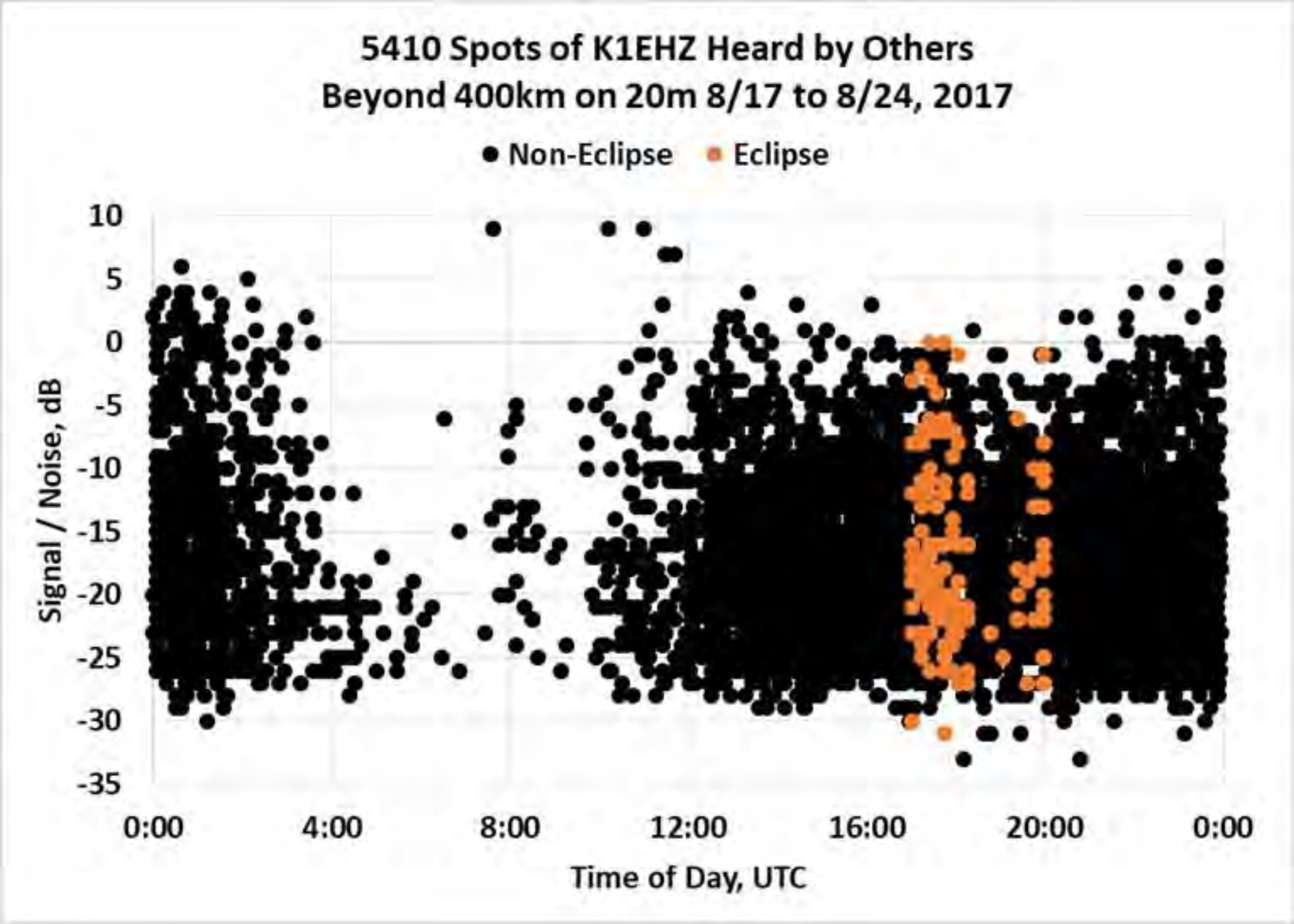




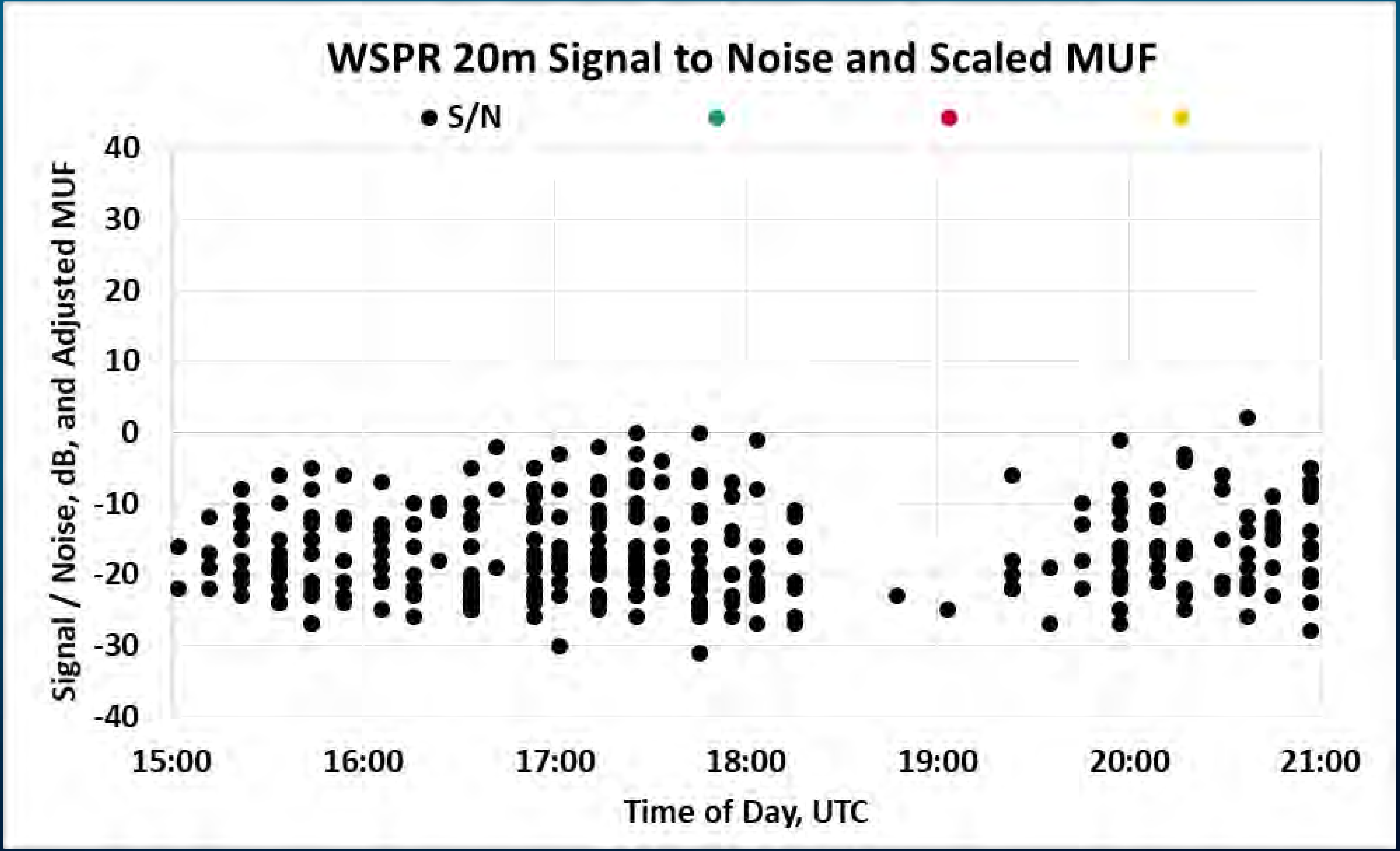


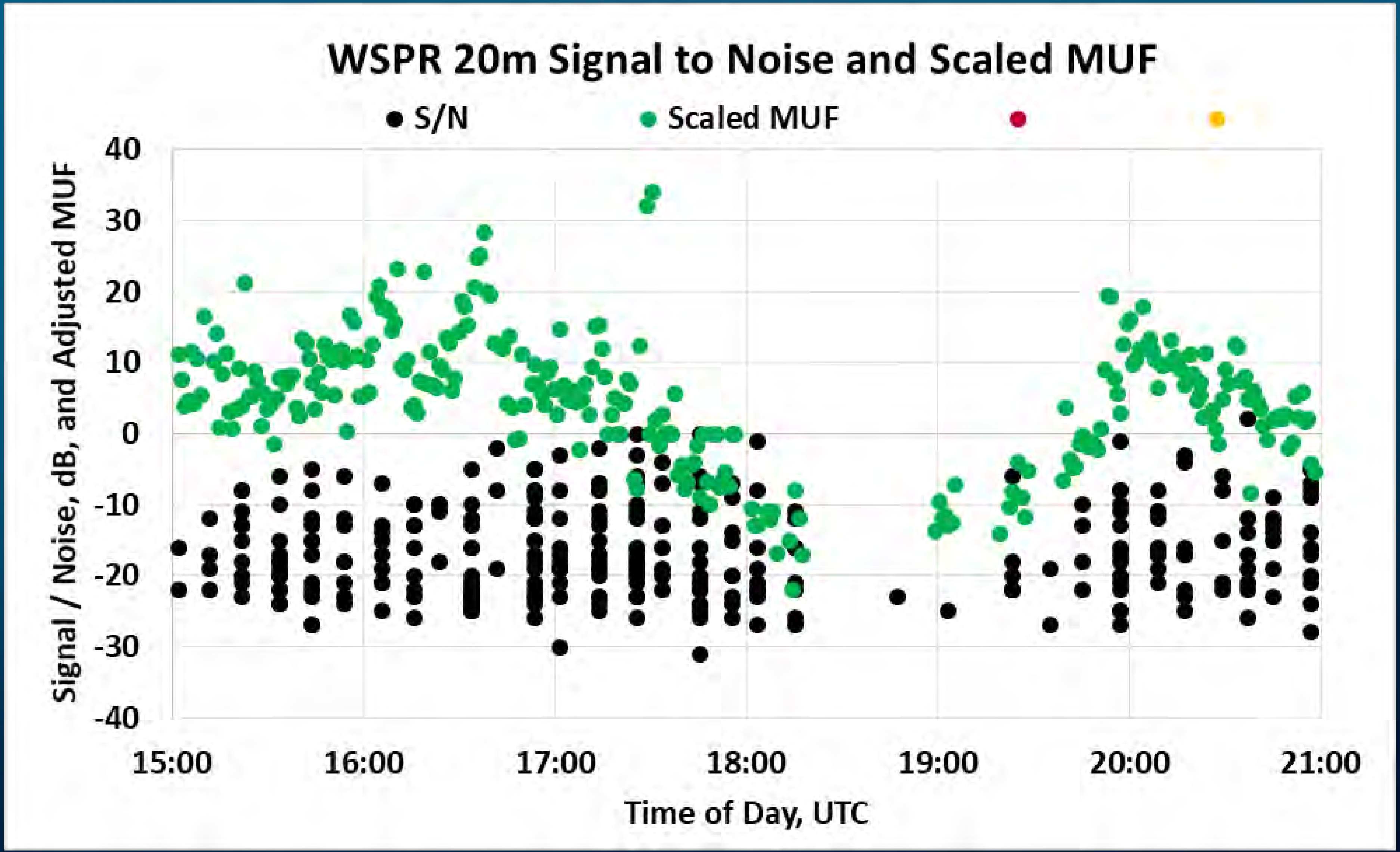
Critical Frequency at Millstone Hill, MA
August 21, 2017
foF2
foF1
foE
Critical Frequency, MHz
5.50
5.00
4.50
4.00
3.50
3.00
2.50
15:00
16:00
17:00
18:00
19:00
20:00
21:00
Time of Day, UTC


MUF for 3000km Skip at Millstone Hill, MA
MUF 8/20, MHz
MUF 8/21, MHz
MUF 8/22, MHz
MUF, MHz
20
19
18
17
16
15
14
13
12
15:00
16:00
17:00
18:00
19:00
20:00
21:00
Time of Day, UTC

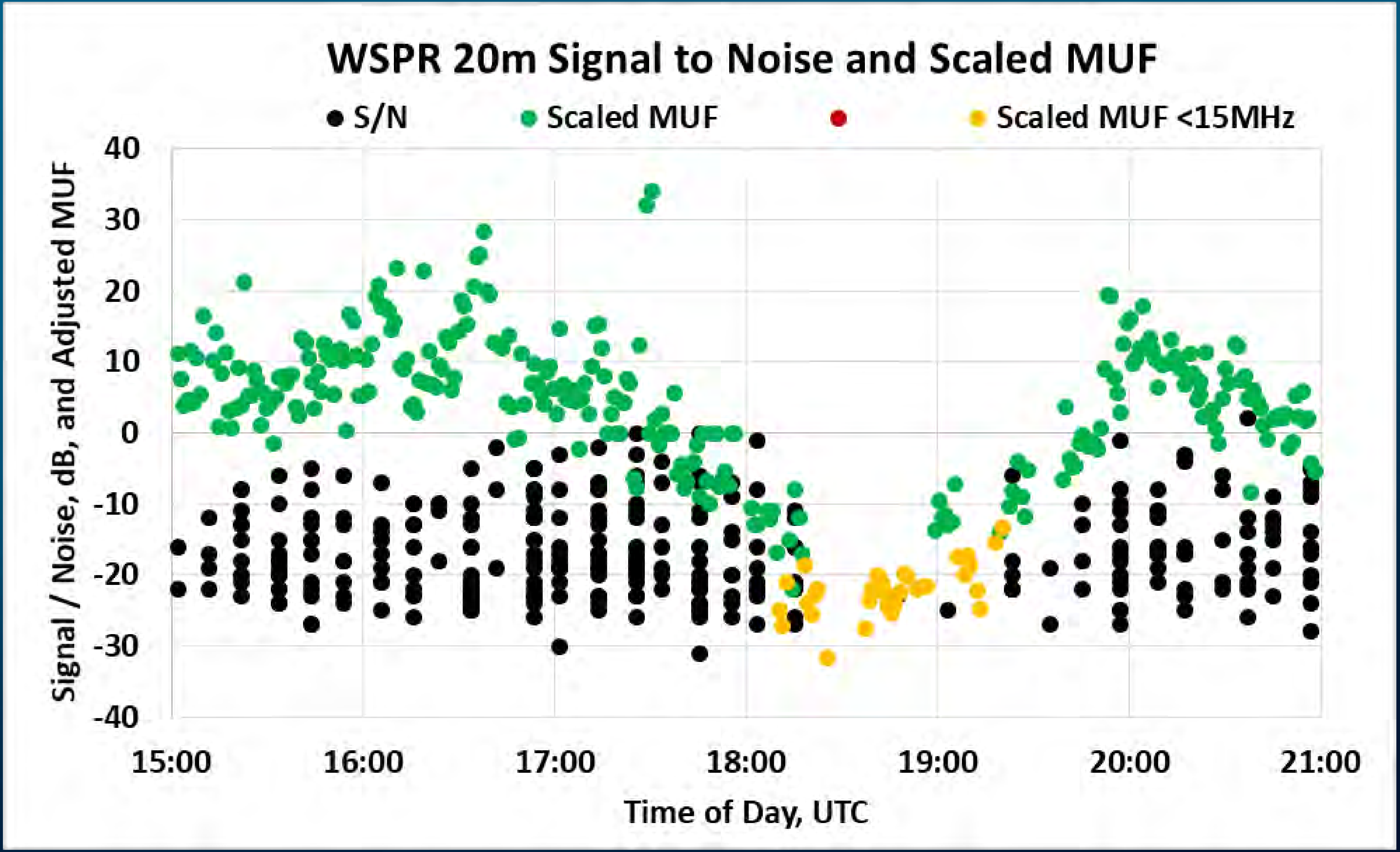


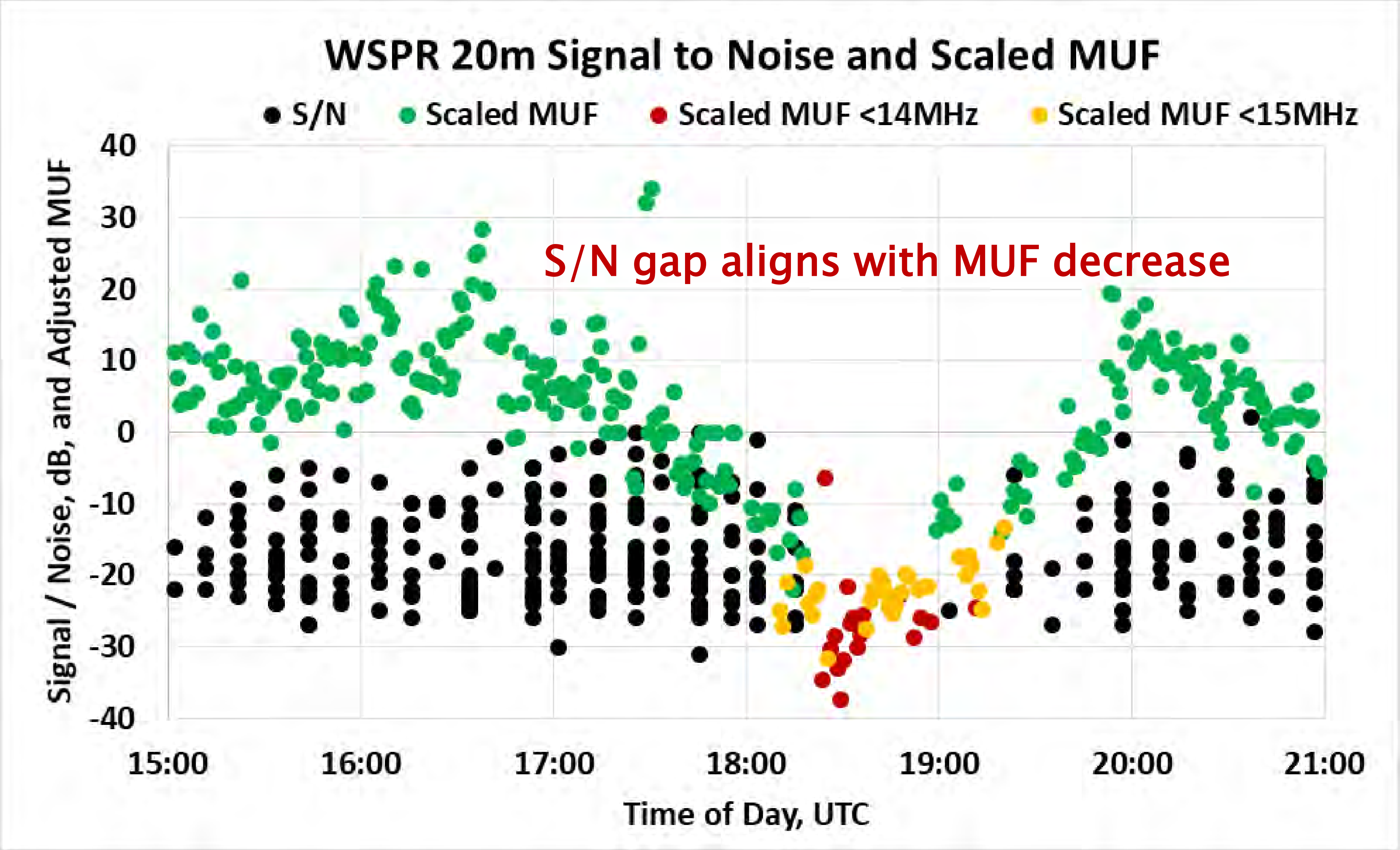
5410 Spots of K1EHZ Heard by Others
Beyond 400km on 20m 8/17 to 8/24, 2017
Non-Eclipse
Eclipse
Signal / Noise, dB
10
5
0
-5
-10
-15
-20
-25
-30
-35
0:00
4:00
8:00
12:00
16:00
20:00
0:00
Time of Day, UTC

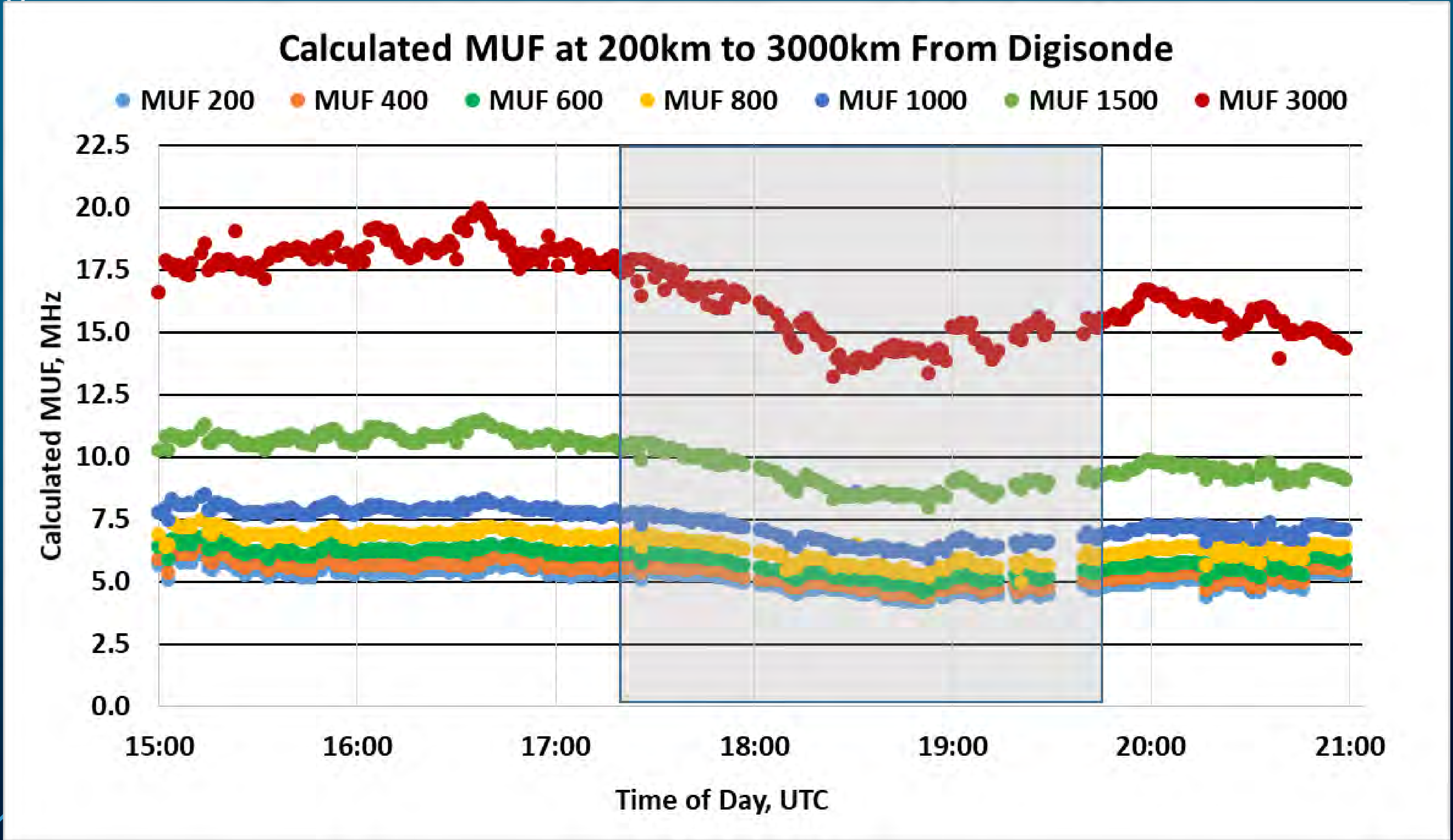

WSPR 20m Signal to Noise and Scaled MUF
S/N
Signal / Noise, dB, and Adjusted MUF
40
30
20
10
0
-10
-20
-30
-40
15:00
16:00
17:00
18:00
19:00
20:00
21:00
Time of Day, UTC



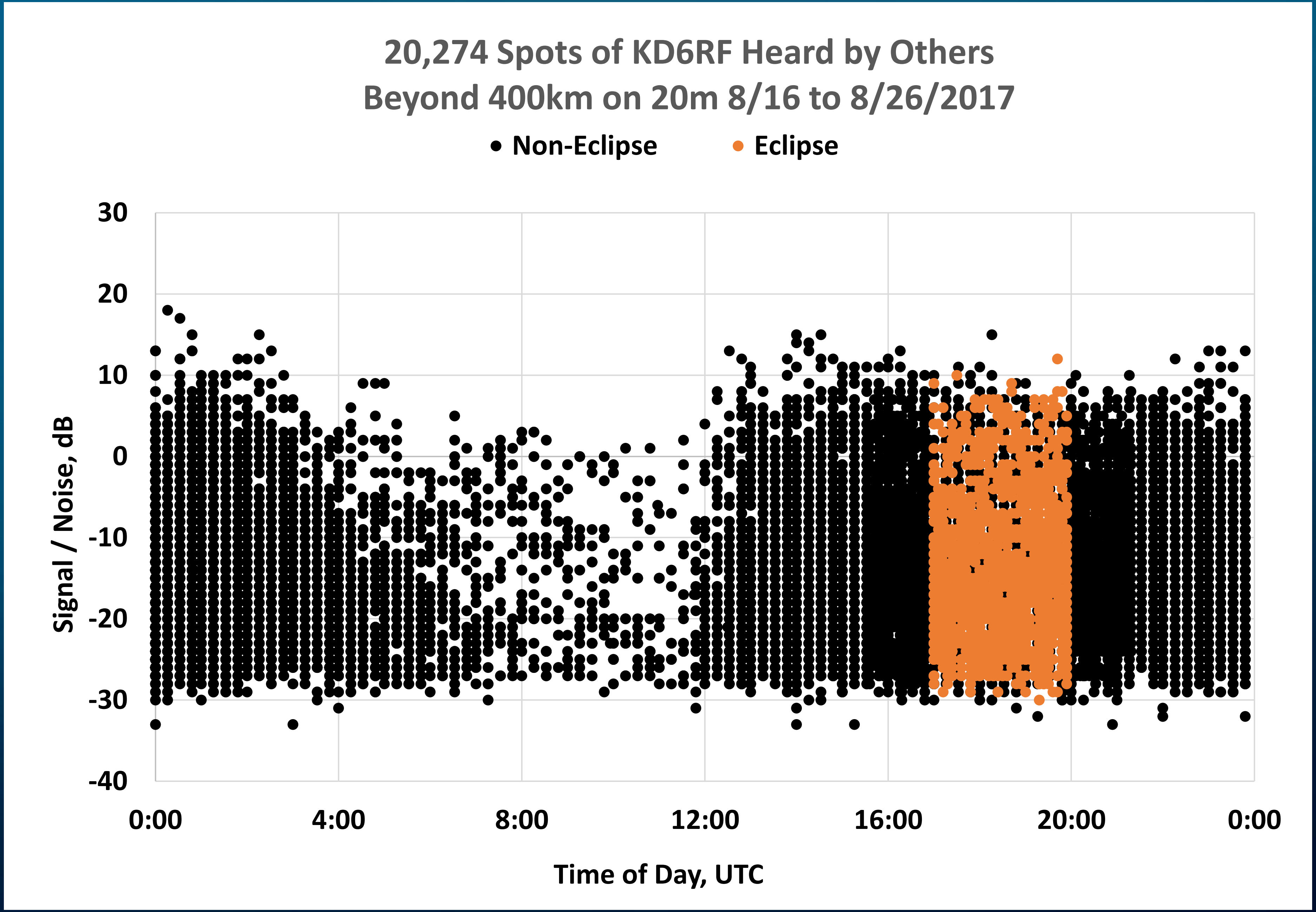
WSPR 20m Signal to Noise and Scaled MUF
S/N
Scaled MUF
Signal / Noise, dB, and Adjusted MUF
40
30
20
10
0
-10
-20
-30
-40
15:00
16:00
17:00
18:00
19:00
20:00
21:00
Time of Day, UTC

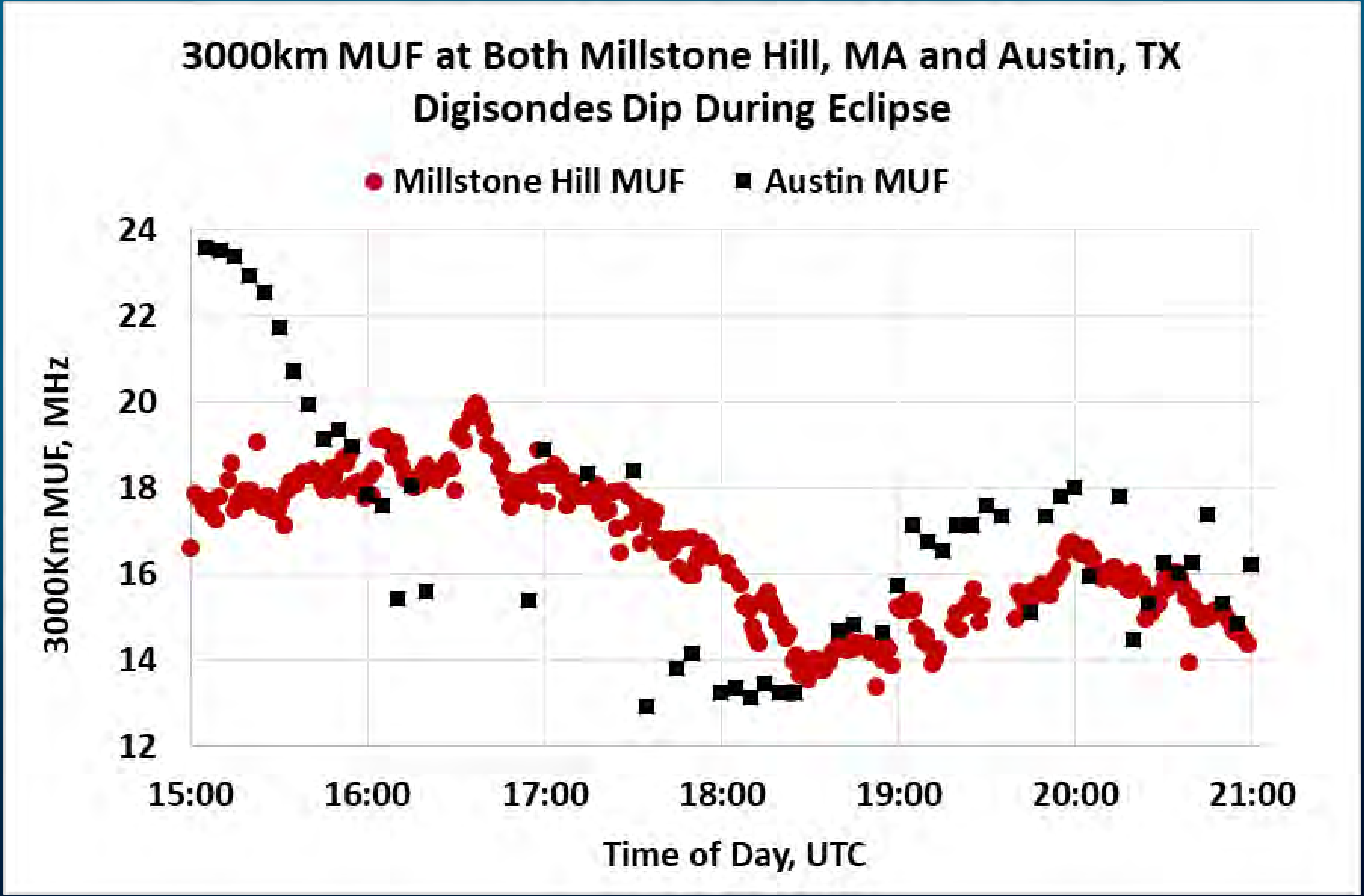

WSPR 20m Signal to Noise and Scaled MUF
S/N
Scaled MUF
Scaled MUF <15MHz
Signal / Noise, dB, and Adjusted MUF
40
30
20
10
0
-10
-20
-30
-40
15:00
16:00
17:00
18:00
19:00
20:00
21:00
Time of Day, UTC

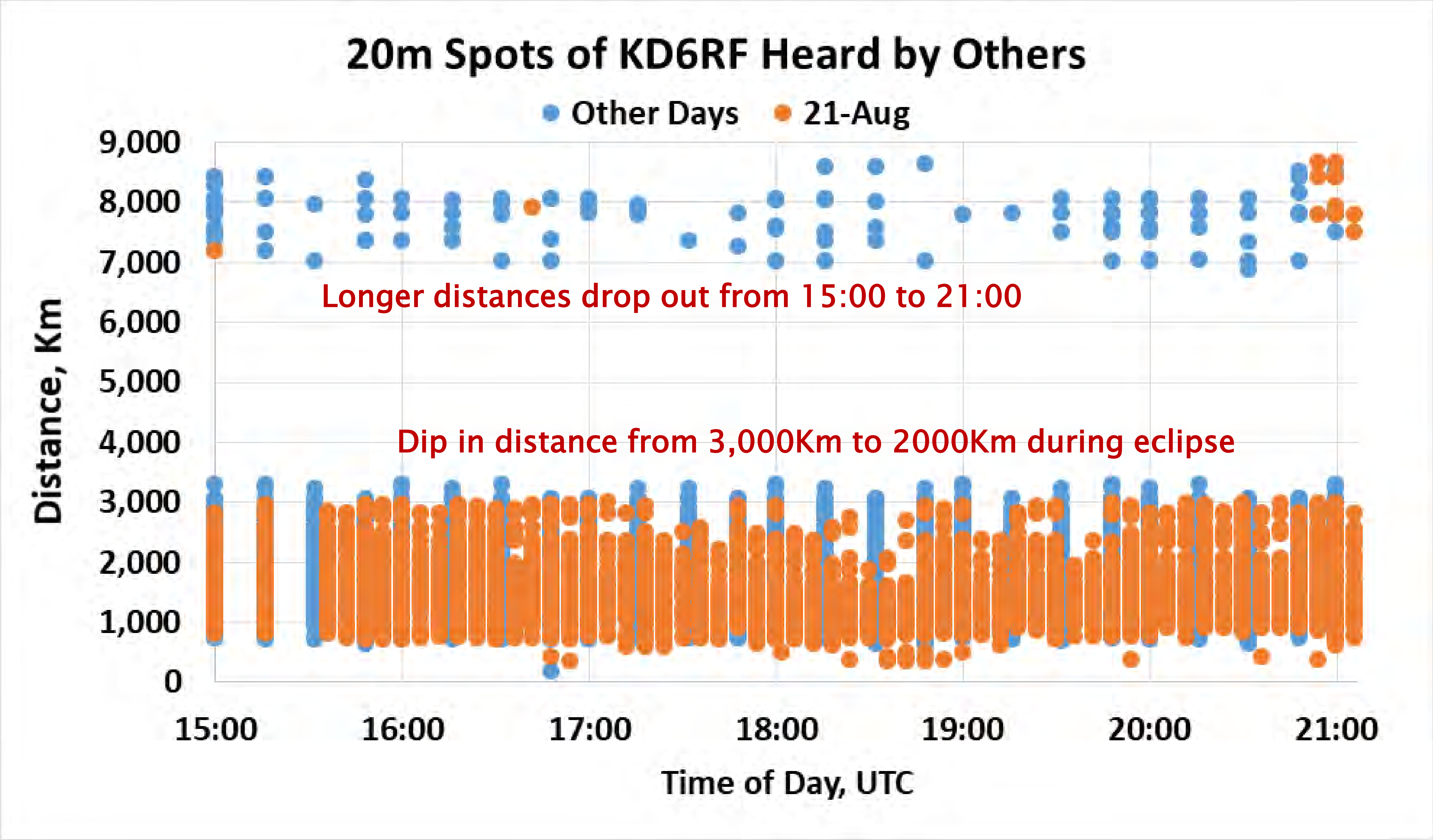

WSPR 20m Signal to Noise and Scaled MUF
S/N
Scaled MUF
Scaled MUF <14MHz
Scaled MUF <15MHz
S/N gap aligns with MUF decrease
Signal / Noise, dB, and Adjusted MUF
40
30
20
10
0
-10
-20
-30
-40
15:00
16:00
17:00
18:00
19:00
20:00
21:00
Time of Day, UTC



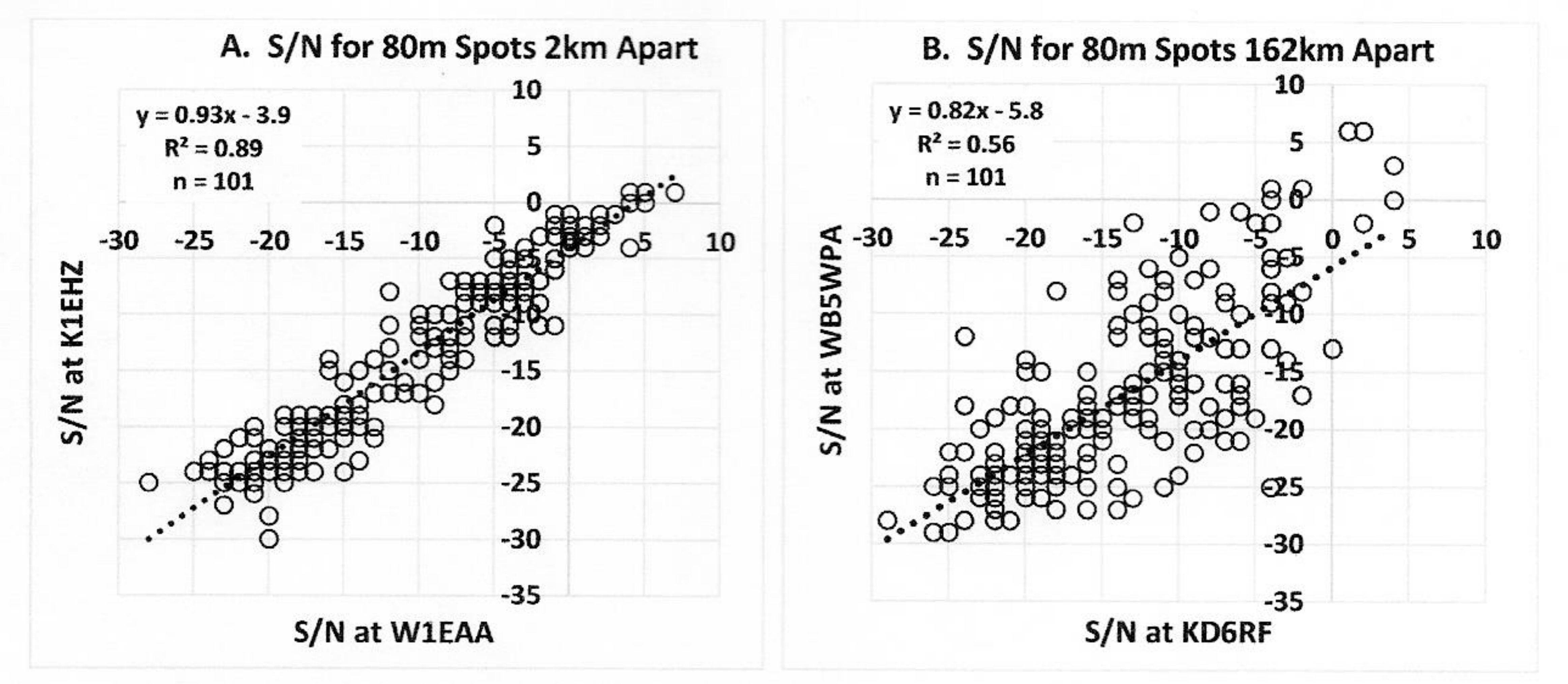
Calculated MUF at 200km to 3000km From Digisonde
MUF 200
MUF 400
MUF 600
MUF 800
MUF 1000
MUF 1500
MUF 3000
Calculated MUF, MHz
22.5
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
15:00
16:00
17:00
18:00
19:00
20:00
21:00
Time of Day, UTC


20,274 Spots of KD6RF Heard by Others
Beyond 400km on 20m 8/16 to 8/26/2017
Non-Eclipse
Eclipse
30
20
10
0
-10
-20
-30
-40
Signal / Noise, dB
0:00
4:00
8:00
12:00
16:00
20:00
0:00
Time of Day, UTC


3000km MUF at Both Millstone Hill, MA and Austin, TX
Digisondes Dip During Eclipse
Millstone Hill MUF
Austin MUF
24
22
20
18
16
14
12
3000Km MUF, MHz
15:00
16:00
17:00
18:00
19:00
20:00
21:00
Time of Day, UTC

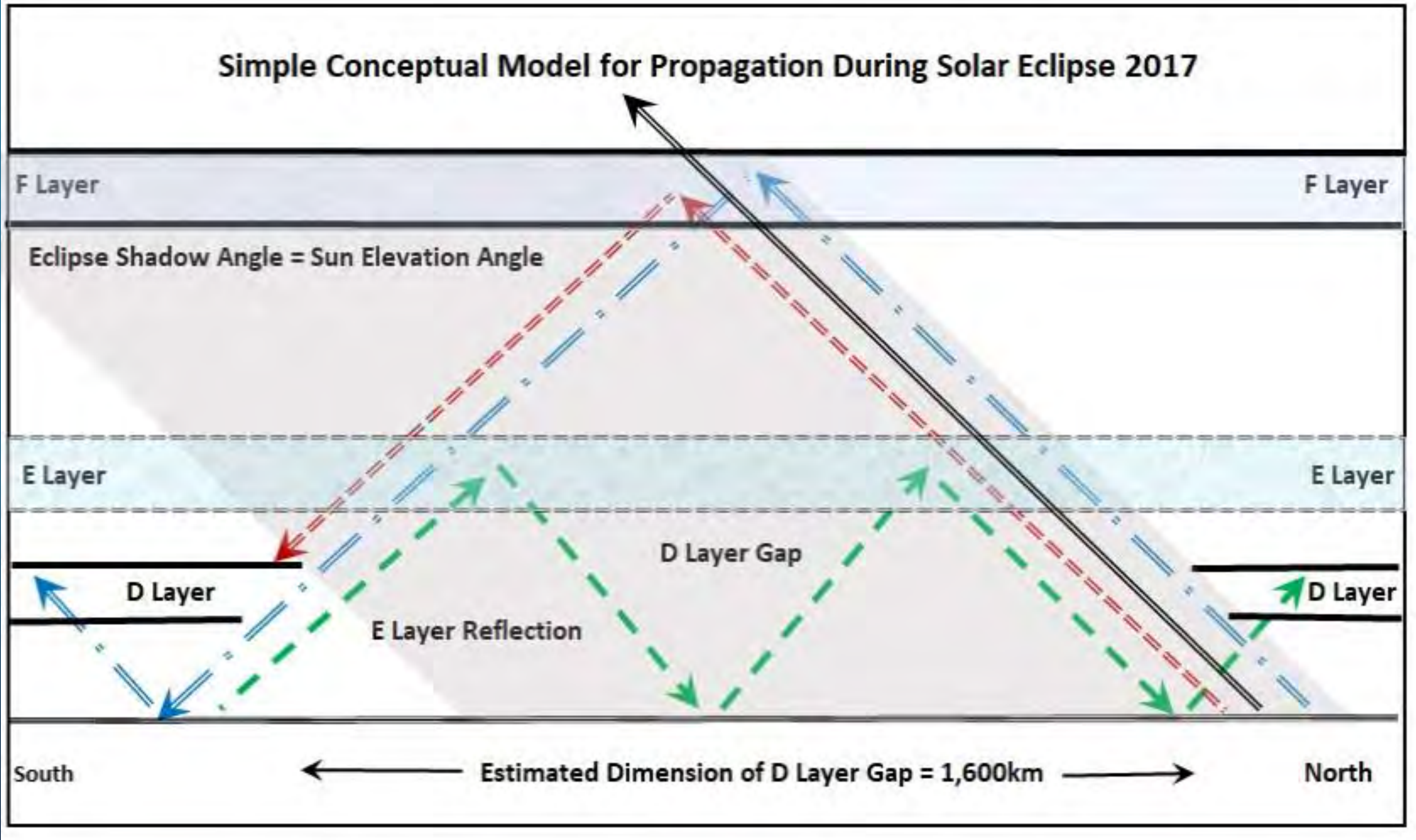

20m Spots of KD6RF Heard by Others
Other Days
21-Aug
Longer distances drop out from 15:00 to 21:00
Dip in distance from 3,000Km to 2000Km during eclipse
Distance, Km
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
15:00
16:00
17:00
18:00
19:00
20:00
21:00
Time of Day, UTC

VARIABILITY AND PATCHINESS FOR SPOTS HEARD BY 2 STATIONS SIMULTANEOUSLY



OVER-SIMPLIFIED ECLIPSE PROPAGATION MODEL

BASED ON OUR DATA THE D LAYER GAP IS ABOUT 1,600KM IN DIAMETER
UMBRA (SHADOW) TRAVELS 2,400KM/HR, OR 1.5 GAP DIAMETERS/HR



INCREASED SIGNAL, DECREASED NOISE, OR BOTH?

- WSPR records and reports Signal / Noise (SNR)
- WSPR doesn't report Signal and Noise separately so we can't determine which, if either, has more effect on SNR
- SNR can go up if Signal goes up, can also go up if Noise goes down. So I emailed Joe Taylor, K1JT, and asked him about it
- *"Eclipse-induced changes in solar noise contributing to your background noise level will be negligible at HF (and even at VHF). Any difference you see in SNR can safely be ascribed to changes in signal level."* Joe Taylor K1JT

RESPONSES TO OUR QUESTIONS

- Based on normal day to night differences in propagation we thought the low bands would be most affected. And 160m and 80 were most affected. 20m experienced decreased propagation. 40m had subtle effects and 630m was not affected.
- All data analyzed had a common limit of signal/noise sensitivity at about -30dB. Local differences in other factors such as terrain, antenna height and antenna orientation can cause signal/noise variations between receiving stations.
- The WSPR database contained data prior to the eclipse and we continued operating for several days after the eclipse to add baseline data, about 330,000 data spots in total.
- The 160m and 80m data contained ground wave and NVIS data, as well as low-angle skywave data. Except for the WS4S signals heard by W3PM, we filtered out ground wave and NVIS by excluding data at distances less than 400km on 160m and less than 600km on 80m.

RESPONSES TO OUR QUESTIONS

- The results on 160m and 80m were stronger signal/noise during the time of the eclipse than on other days at the same time of day. The stronger signals lasted for 8 to 24 minutes even though eclipse darkening lasted longer.
- Enhanced propagation extended from the area of totality out to about 80% of totality on 160m. The gap seemed wider or patchier on 80m out to 65% totality.
- Our data for 160m suggest the D layer gap is about 1,600km in diameter occupying an area of about 5,000km^2 at any given moment. For 80m the D layer gap may be wider or patchier.
- Our observations are consistent with a conventional propagation model.
  - Darkening during an eclipse briefly disrupts D layer absorption creating gaps or patches that allow radio waves to be reflected from the E or F layers where critical frequencies may also be affected.
  - MUF may also be reduced causing higher frequencies (14MHz) to fall above the critical frequency thereby changing propagation distance.

SUMMARY

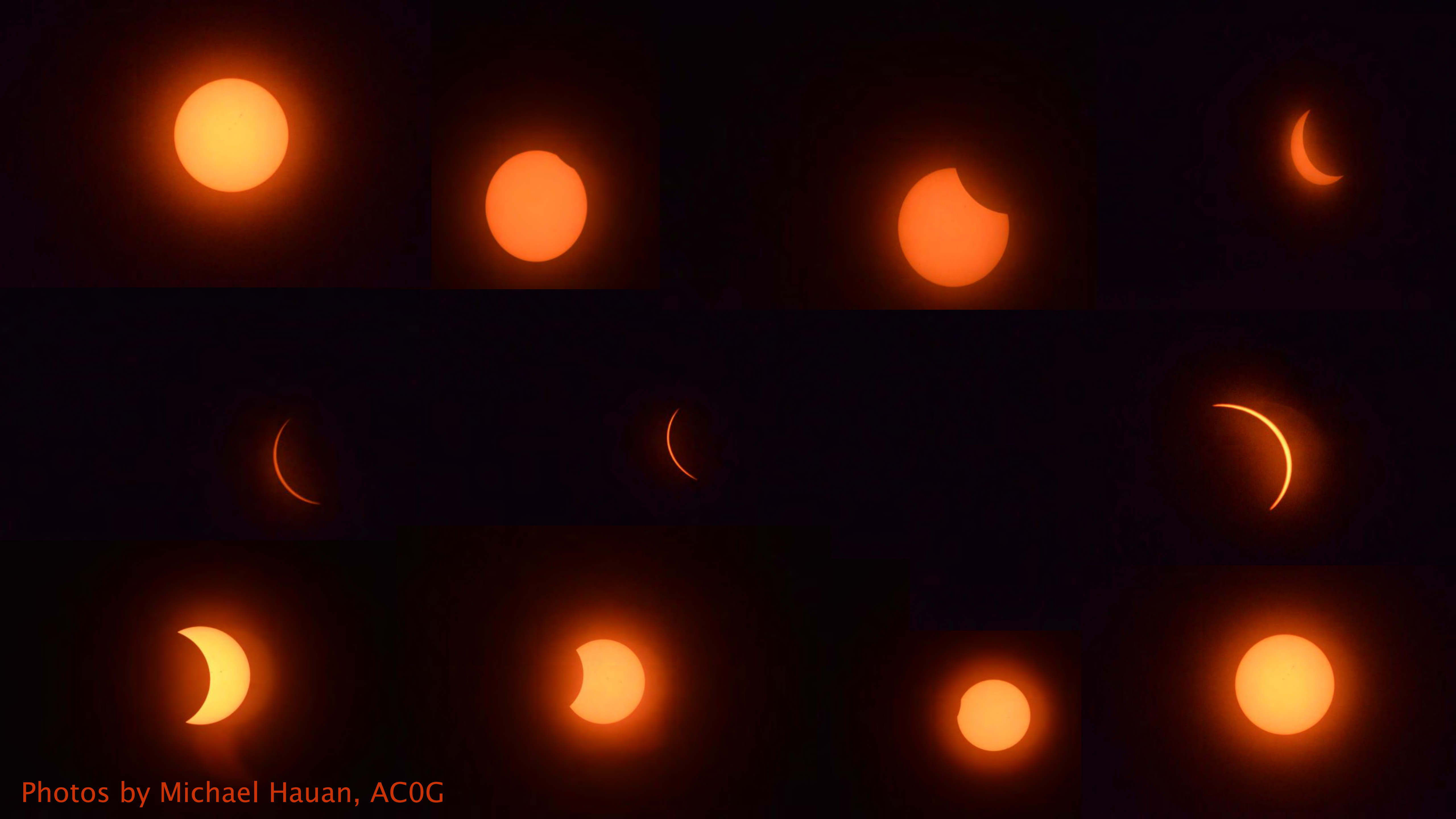
- On 160m and 80m were stronger signal/noise during the eclipse than on other days at the same time of day. Stronger signals lasted for 8 to 24 minutes even though eclipse darkening lasted longer.
- Eclipse effects are short duration so WSPR transmissions must be timed accordingly – some stations transmitting constantly and others receiving constantly.
- Enhanced propagation extended from the area of totality out to about 80% of totality on 160m. The gap seemed wider or patchier on 80m out to 65% totality.
- 160m data suggest the D layer gap is about 1,600km in diameter occupying an area of about 5,000km^2 at any given moment. For 80m the D layer gap may be wider or patchier.

SUMMARY

- Our observations are consistent with a conventional propagation model.
  - Darkening during an eclipse briefly disrupts D layer absorption creating gaps or patches that allow radio waves to be reflected from the E or F layers where critical frequencies may also be affected.
  - MUF may also be reduced causing transmissions on 40m and 20m to fall above the critical frequency thereby changing propagation distance.

SUMMARY

- 160m and 80 were most affected by light – dark differences.
- 20m experienced decreased propagation.
- 40m had subtle effects
- 630m was not affected
- Importantly, subtle effects on 40m were difficult to identify in the WSPR data.
- This underscores the usefulness of direct QSO information to highlight the subtleties.



Photos by Michael Hauan, AC0G