

# HamSCI and the 2017 Total Solar Eclipse

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Nathaniel A. Frissell, W2NAF<sup>1</sup>  
and the HamSCI Community

<sup>1</sup>New Jersey Institute of Technology, K2MFF

# Total Solar Eclipse

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[https://github.com/HamSCI/eclipse\\_calculator](https://github.com/HamSCI/eclipse_calculator)



# 300 km – 0 km Altitude

BLUE: More Eclipsed @ 300 km Alt

RED: More Eclipsed on Ground



[https://github.com/HamSCI/eclipse\\_calculator](https://github.com/HamSCI/eclipse_calculator)

# HamSCI Eclipse Experiments

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- **HF Frequency Measurement Experiment**

- Measure changes in WWV, CHU frequency due to eclipse

- **Solar Eclipse QSO Party (SEQP)**

- Ham Radio Contest-Like Event
- Generate a quasi-random dataset
- Data from RBN, PSKReporter, WSPRNet, Logs

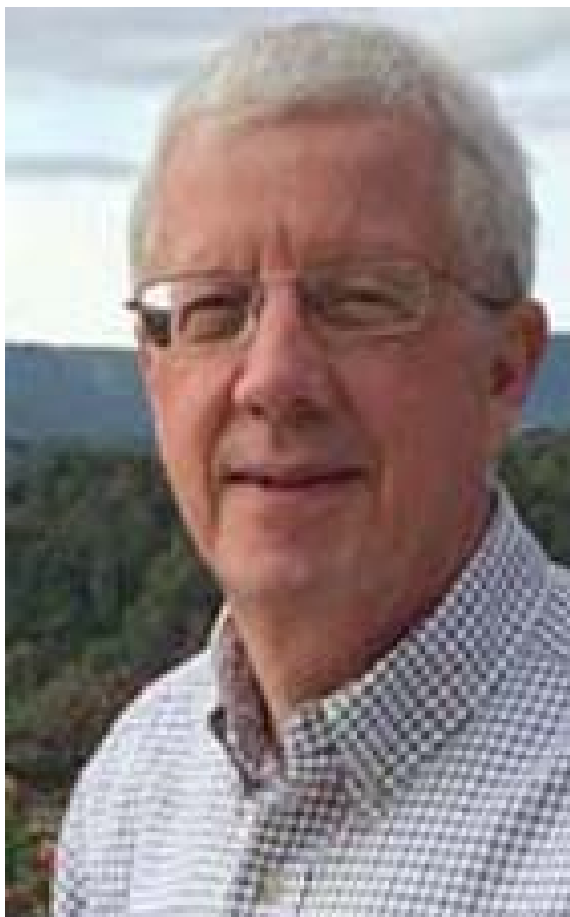
- **HF Wideband Recording**

- Use SDRs to record large amounts of HF Spectrum



# Steve Reyer, PhD, WA9VJ (SK)

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Steve Reyer  
1950-2018

- Professor Emeritus of Electrical Engineering at the Milwaukee School of Engineering
- Teacher and Industry Consultant
  - digital signal processing
  - communications
  - microprocessors
  - circuits
  - Senior Design
- Active in FMT Community
- Very important for HamSCI Eclipse Frequency Measurement Experiment

# HF Frequency Measurement Experiment

The screenshot shows a web browser window with the URL `hamsci.org/2017-eclipse-hf-frequency-measurement-experiment`. The page features the HamSCI logo and navigation menu. The main heading is "2017 Eclipse HF Frequency Measurement Experiment". A yellow box contains a request to bookmark the page and join the HamSCI-Eclipse mailing list. A paragraph explains the scientific basis of the experiment, citing Doppler shifts on HF ray paths. The page is organized into sections: "Research Question" (How does the 2017 Total Solar Eclipse affect HF propagation paths?), "Objective" (Measure HF path Doppler shifts caused by the motion of the eclipse shadow across the ionosphere), "Times" (Control Day: August 20, 2017, 1400 – 2200 UTC; Eclipse Day: August 21, 2017, 1400 – 2200 UTC), and "Beacons" (WWV in Fort Collins, CO, 2.5 MHz). An inset window displays a map of the United States with a data popup for a partial solar eclipse on August 21, 2017, at 40° 40' 46.90" N, 105° 02' 32.74" W. The popup includes coordinates, event name, obscuration (95.730%), magnitude at maximum (0.96048), moon/sun size ratio (1.02977), and a table of event times.

2017 Eclipse HF Frequency Me X

Not Secure | hamsci.org/2017-eclipse-hf-frequency-measurement-experiment

HamSCI About Projects Get Involved People Resources Publications

## 2017 Eclipse HF Frequency Measurement Experiment

Please bookmark this page and join the **HamSCI-Eclipse mailing list** for further announcements.

Rapid changes in ionospheric electron density caused by the motion of the shadow of an eclipse is known to cause Doppler shifts on HF ray paths propagating through the eclipse region. For example, see Figure 7 in **Boitman et al., 1999**. We request that all amateur radio stations capable of making high-quality HF frequency measurements participate in this experiment and publish their data to the **HamSCI community on the open-data sharing site zenodo.org**.

### Research Question

- How does the 2017 Total Solar Eclipse affect HF propagation paths?

### Objective

- Measure HF path Doppler shifts caused by the motion of the eclipse shadow across the ionosphere.

### Times

- Control Day: August 20, 2017, 1400 – 2200 UTC
- Eclipse Day: August 21, 2017, 1400 – 2200 UTC

Note: Partial eclipse begins 21 Aug 2017 at about 1600 UTC in Oregon ends at 21 Aug 2017 at about 2015 UTC in South Carolina.

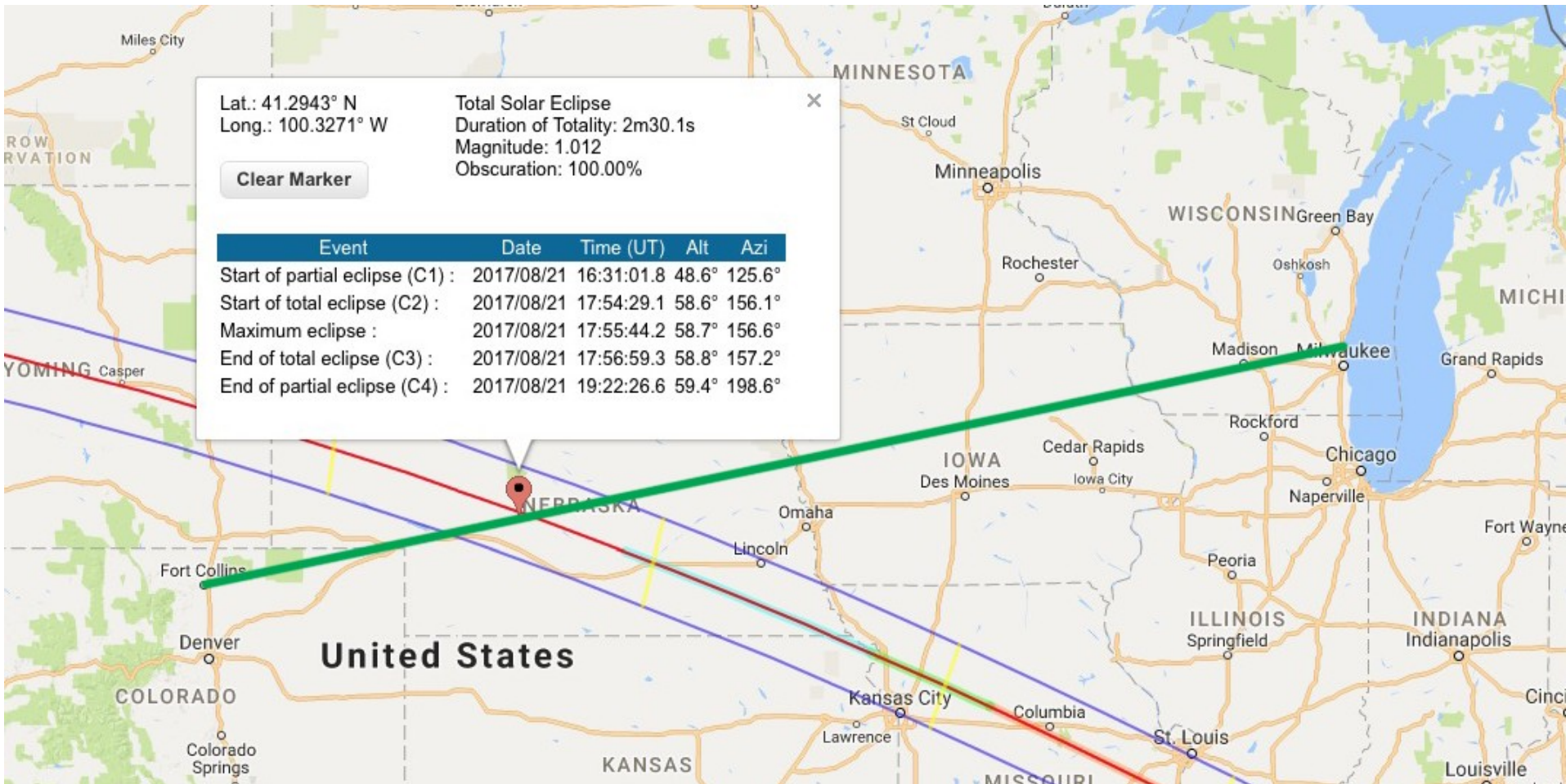
### Beacons

WWV in Fort Collins, CO  
• 2.5 MHz

40° 40' 46.90" N <-> 40.67969° (partial solar eclipse) Help X  
105° 02' 32.74" W <-> -105.04243°  
Obscuration : 95.730% Max Magnitude at maximum : 0.96048  
Moon/Sun size ratio : 1.02977

Event (ΔT=68.8s)	Date	Time (UT)	Alt	Azi	P	V
Start of partial eclipse (C1)	2017/08/21	16:23:26.6	+44.7°	117.9°	291°	12.8
Maximum eclipse (MAX)	2017/08/21	17:46:43.5	+56.6°	144.3°	020°	10.4
End of partial eclipse (C4)	2017/08/21	19:13:48.0	+61.1°	185.4°	108°	08.5

# WA9VNJ 10MHz WWV Observations





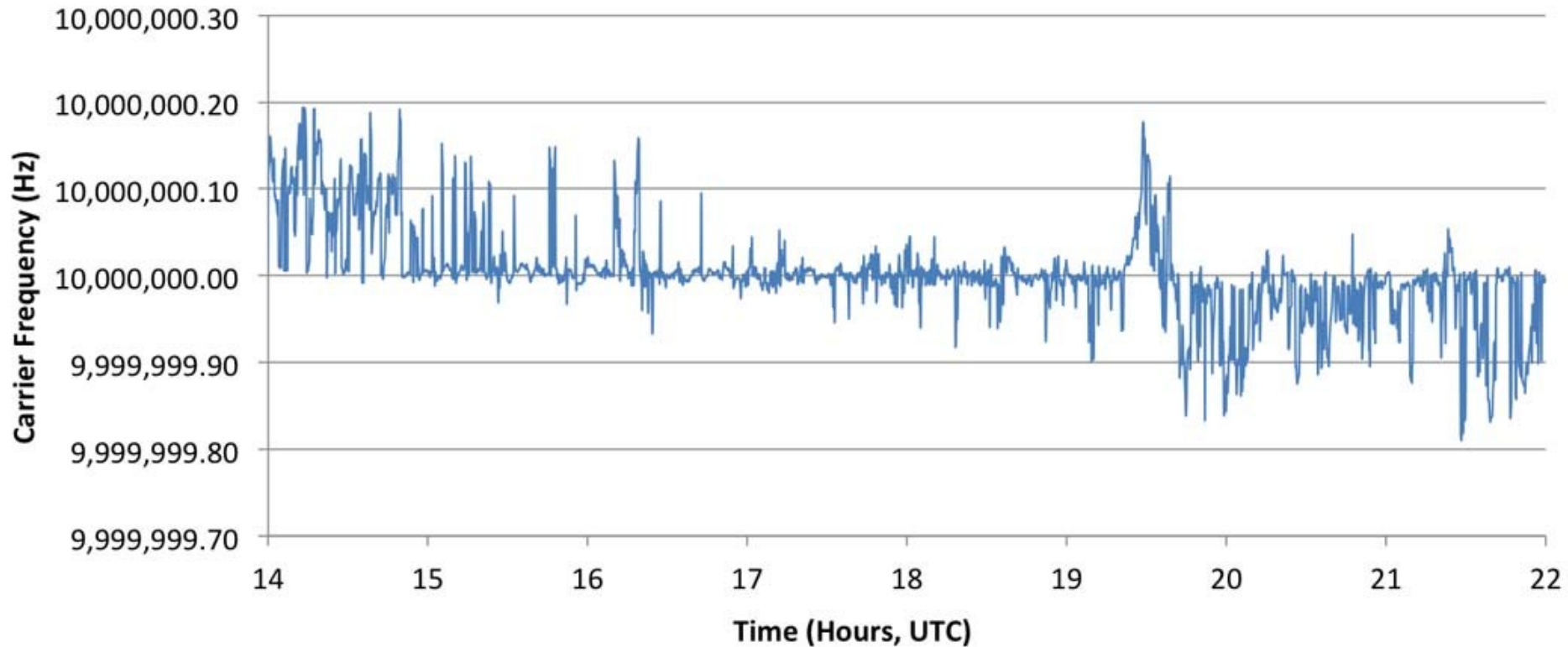
# WA9VNJ Instrumentation

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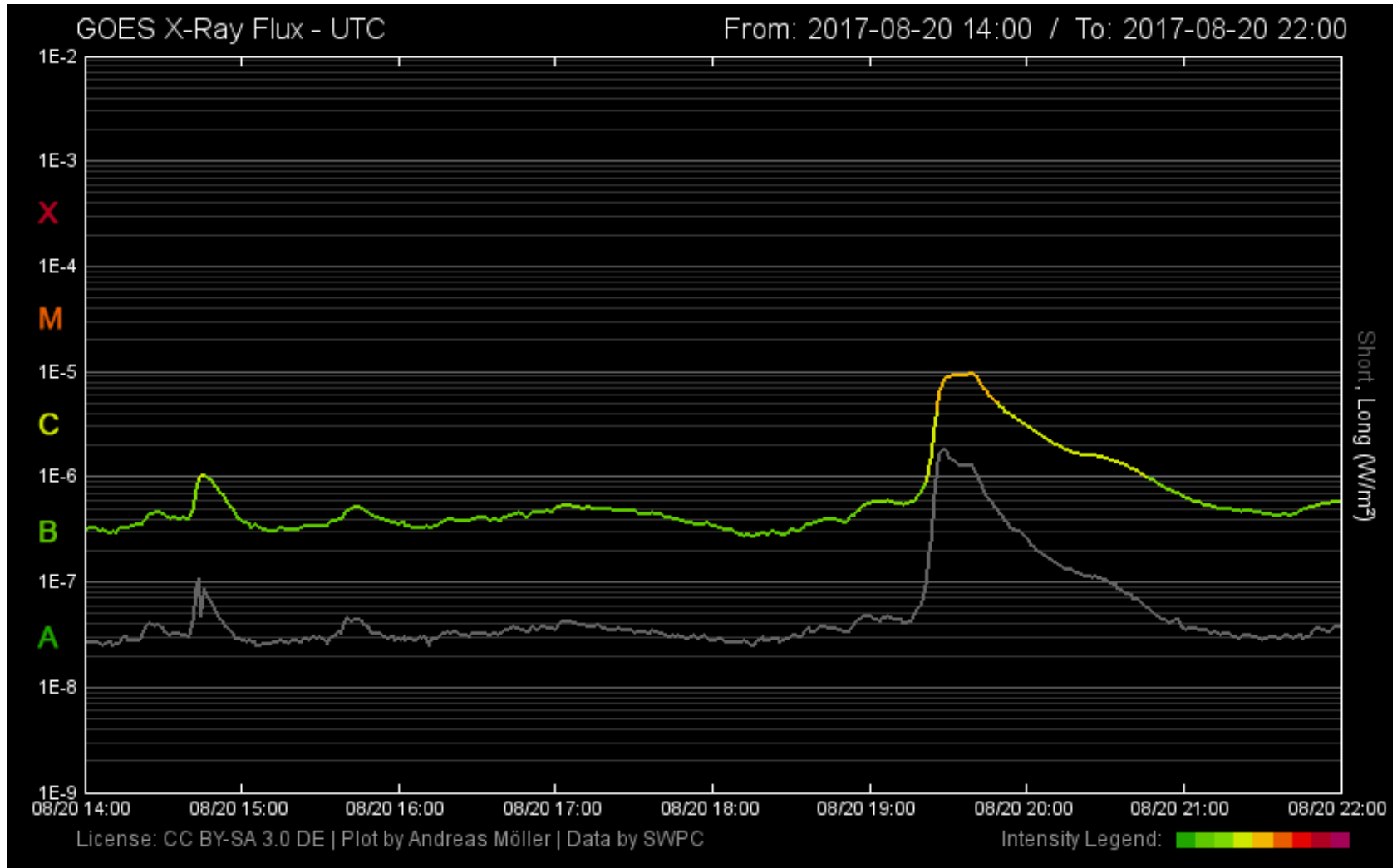
- **Radio:** Yaesu FT-857D with XRef-FT oscillator interface driven by a Trimble Thunderbolt GPSDO
- **Calibration:** Rigol DG1022Z signal generator locked to a second TBolt for reference signals.
- **Antenna:** DX Engineering RF-PRO-1B aimed N-S
- **Software:** Spectrum Lab (SL) and custom DSP software.

# WA9VNJ 10MHz WWV Observations

**WWV 10 MHz Carrier Frequency, 8/20/17 (Control Day)  
Received Near Milwaukee, WI. Mean=10,000,000.0022 Hz**



# GOES X-Ray Flux – Control Day

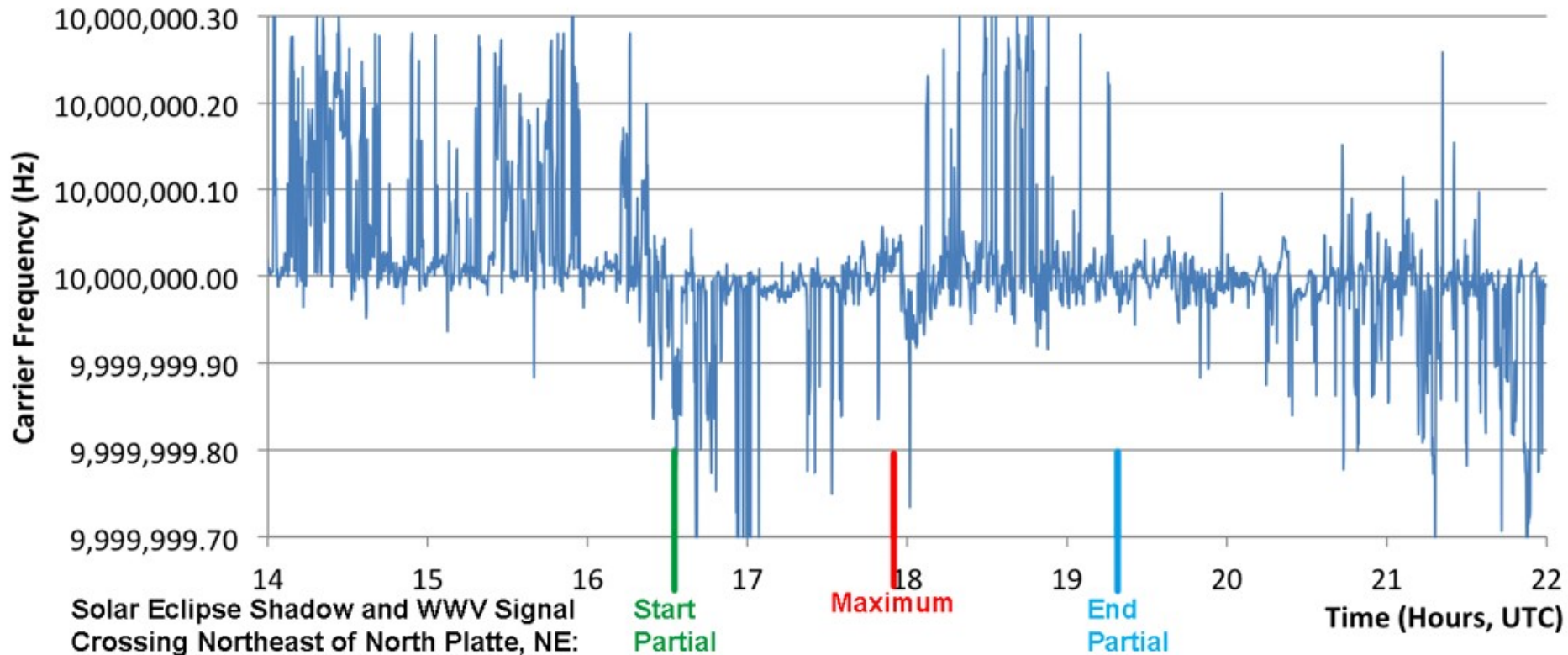


[http://www.polarlicht-vorhersage.de/goes\\_archive](http://www.polarlicht-vorhersage.de/goes_archive)



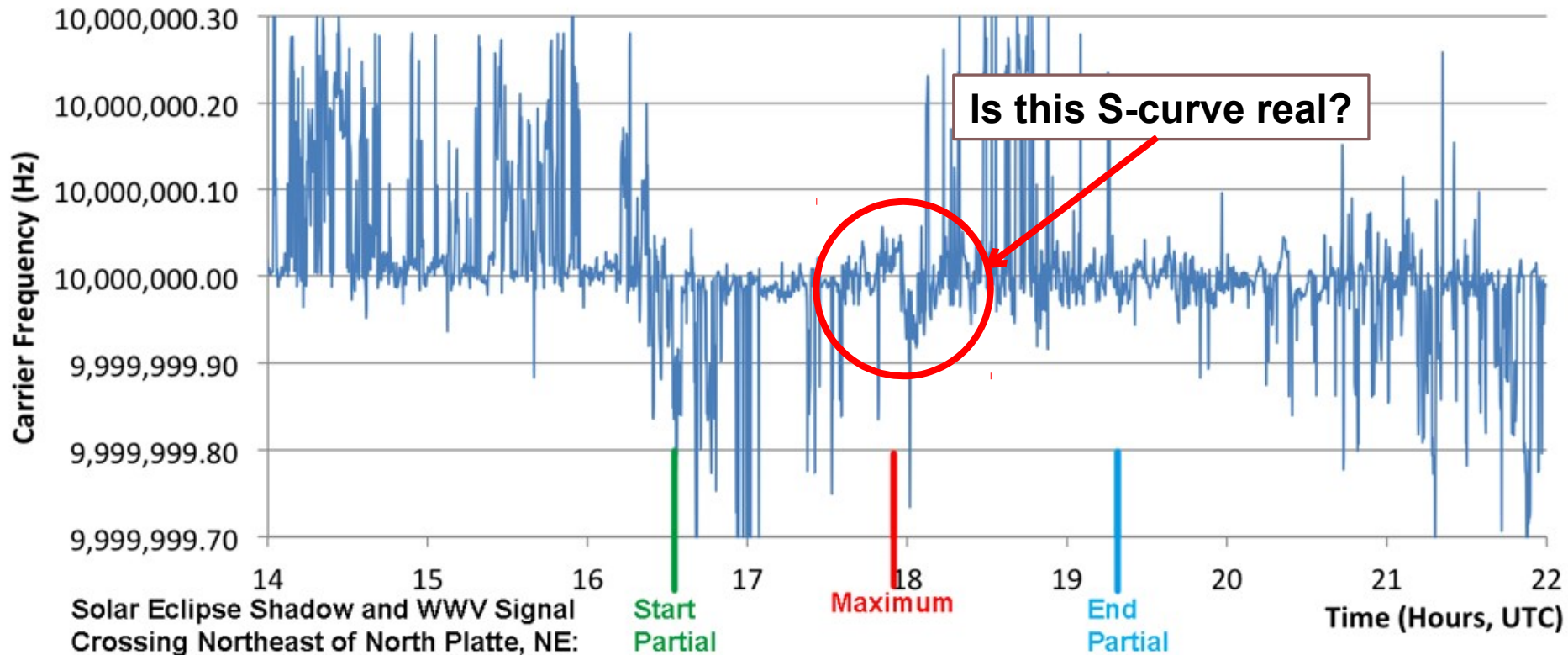
# WA9VNJ 10MHz WWV Observations

WWV 10 MHz Carrier Frequency, 8/21/17 (Eclipse Day)  
Received Near Milwaukee, WI. Mean=10,000,000.0096 Hz



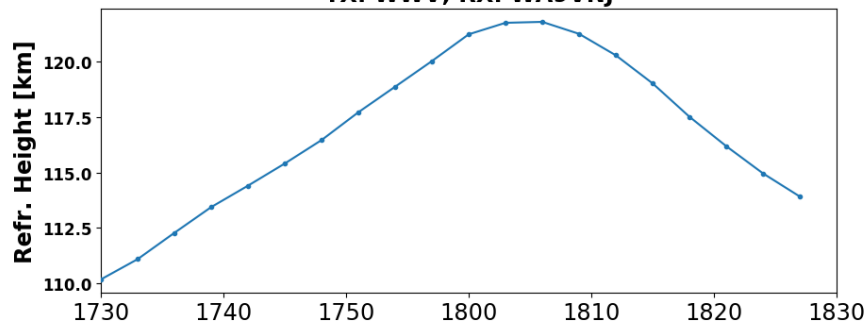
# WA9VNJ 10MHz WWV Observations

WWV 10 MHz Carrier Frequency, 8/21/17 (Eclipse Day)  
Received Near Milwaukee, WI. Mean=10,000,000.0096 Hz

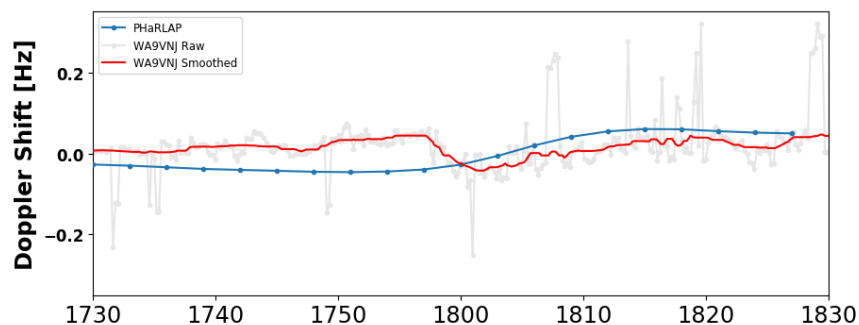


# WA9VNJ/PHaRLAP/GOES

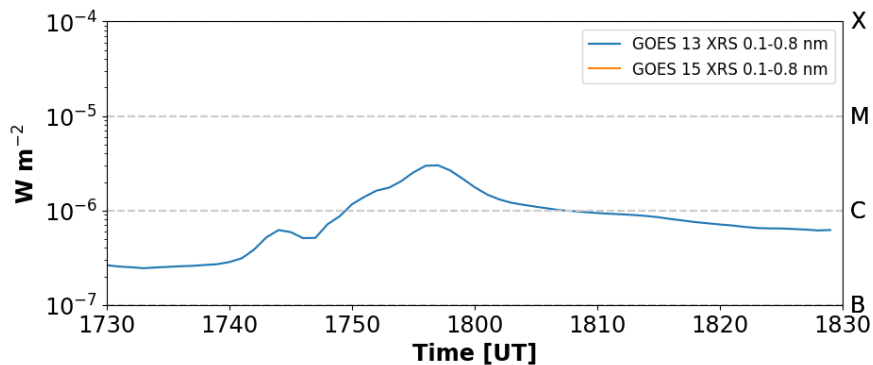
2017 Aug 21 17:30 UT - 2017 Aug 21 18:30 UT  
TX: 40.68°N, -105.04°E; RX: 43.22°N, -87.95°E, Frequency: 10.000 MHz  
TX: WWV; RX: WA9VNJ



PHaRLAP/SAMI3



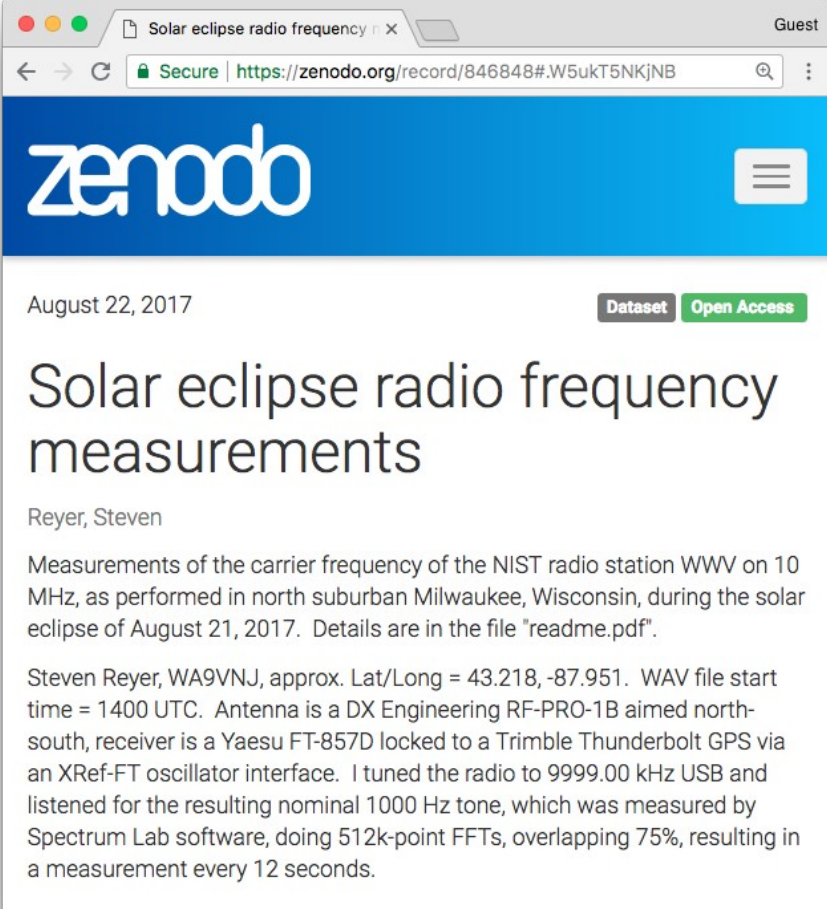
WA9VNJ  
PHaRLAP/SAMI3



GOES X-RAY

# WA9VNJ Conclusions

- Doppler shifts observed for
  - Dawn and Dusk
  - Eclipse Onset and Recovery
  - Solar Flares
- Small solar flares can have a pronounced effect
  - C2-Class flare caused 0.05 Hz shift!
- We don't understand the short-term variability.



The screenshot shows a web browser window with the URL <https://zenodo.org/record/846848#.W5ukT5NKjNB>. The page features the Zenodo logo and a blue header. The main content area displays the title "Solar eclipse radio frequency measurements" by Steven Reyer, dated August 22, 2017. The page includes a "Dataset" label and an "Open Access" button. The abstract text describes measurements of the carrier frequency of the NIST radio station WWV on 10 MHz during the solar eclipse of August 21, 2017. It also provides details about the equipment used, including a DX Engineering RF-PRO-1B antenna and a Yaesu FT-857D receiver, and mentions the use of Spectrum Lab software for data analysis.

<https://zenodo.org/communities/hamsci>



# HamSCI Eclipse Research Questions

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- Can we use HF ham radio communications to observe eclipse effects on the ionosphere?
- Can we use data-model comparisons to:
  - Better understand the ham radio data?
  - Constrain or calibrate the model?



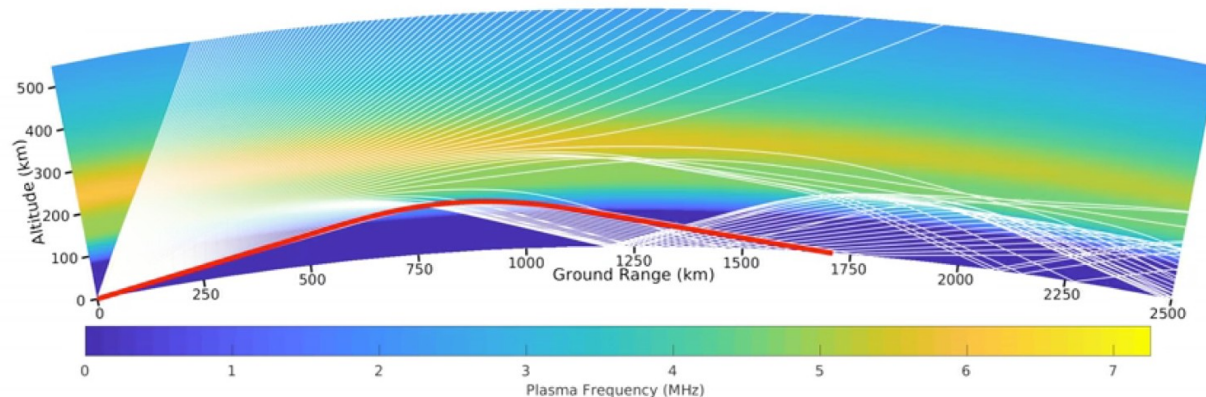
# Amateur Radio and the HF Bands

## Frequency      Wavelength

1.8 MHz	160 m
3.5 MHz	80 m
7 MHz	40 m
10 MHz	30 m
14 MHz	20 m
18 MHz	17 m
21 MHz	15 m
24 MHz	12 m
28 MHz	10 m
50 MHz	6 m



*K2MFF, The NJIT  
Ham Radio  
Station*



**1600 UT 21 Aug 2017 14.03 MHz - Eclipsed SAMI3  
TX: AA2MF (Florida) RX: WE9V (Wisconsin)**

# CW Skimmer and RBN

CW Skimmer 1.1 - Registered to Pete Smith

File View Help

7014.89

Call signs on the right: CQ OM3LA, CQ K1RX, CQ WC1M, CQ VY2TT, UU7J 599, HABA

Decoders: 199 of 377

TIn: 1 user

main page - Reverse Beacon Network

www.reversebeacon.net/main.php

REVERSE BEACON NETWORK

SSN:136 SFI:146 A:7 K:2 callsign lookup:

options: showhide

news: RBN blog: stay tuned! we have 106 skimmers online

skimmers online:

- AA4VW - 20m,30m,40m,17m,15m
- ACDC - 10m,20m,30m,17m,15m
- BG8FFE - 20m,15m
- DB0MMQ - DF4UE - 10m,20m,40m,17m,12m,15m
- DF7GB - 10m,20m,40m,17m,12m,15m
- DJ9IE - DK8NE - DK9IP - 20m,30m,40m,17m,15m
- DL0LBS - DL1EMY - 20m,40m,17m,15m
- DL2CC - 20m,30m,40m,17m,15m
- DL3KR - 40m
- DL3LAS - 20m,40m,15m
- DL9GTB - 20m,30m,40m,17m,12m,15m
- DO4DXA - 15m
- RP1A

de	dx	freq	cq/dx	snr	speed	time
JE1SGH	UN7AB	21040.0	CW CQ	12 dB	27 wpm	1334z 05 Sep
BG8FFE	RM6F	14043.3	CW CQ [LoTW]	14 dB	26 wpm	1334z 05 Sep
R6YY	IW2ODG	21000.0	CW CQ	3 dB	15 wpm	1334z 05 Sep





# Solar Eclipse QSO Party (SEQP)

- **August 21, 2017 from 1400 – 2200 UT**

- **Contest-like (I really wanted this!)**

- 2 Points CW or Digital
- 1 Point for Phone
- Multiply Score by # of Grids

- **Exchange**

- RST + 6 Character Grid Square

- **Data sources**

- Reverse Beacon Network
- PSKReporter
- WSPRNet
- Participant-submitted logs



<http://hamsci.org/seqp>



# Solar Eclipse QSO Party

- 570 parsed logs
- 29,809 QSOs
- 4,929 unique callsigns
- 649 4-char grid squares
- 80 DX Entities

*(from logs submitted to hamsci.org)*



# SEQP Observations

**REVERSE BEACON NETWORK**

Check out RBN's blog at: <http://reversebeacon.blogspot.com>, stay tuned!

options: [showhide](#)

news: [RBN blog: stay tuned!](#)

we have 142 skimmers online

skimmers online:

- 3B8CW - 20m
- 7LAIUJ - no spot last 15min
- SMQNCG - 20m
- BV1RM - 40m, 30m
- AA4VV - 40m, 20m, 17m
- AC3C - no spot last 15min
- BD2FW - no spot last 15min
- BQ0ARE - 20m
- BG1NBE - 30m, 20m
- BH4RRG - no spot last 15min
- DF4UE - 80m, 40m, 30m, 20m, 17m
- DF4XX - 80m, 40m, 20m
- DJ3AK - no spot last 15min
- DJ3IE - 40m, 30m, 20m, 17m
- DK0TE - 40m, 20m
- DK3JA - 40m, 30m
- DK3NE - 6m
- DK3PF - 40m, 30m, 20m
- DL4KR - 40m, 20m
- DL4RCK - 20m
- DL4ZF - 10m
- DL4BLAS - 80m, 40m, 30m, 20m, 17m
- DL4STB - 80m, 40m, 30m, 20m, 17m
- DO4DXA - 80m, 40m, 20m, 17m
- EASWU - 40m, 30m, 20m, 17m, 15m, 12m
- EASVQ - no spot last 15min

dx	freq	cx/dx	snr	speed	time
EASWU	DJ1YFK	21025.2 CW CQ [L,OTW]	11 dB	27 wpm	1549z 22 Jun
KHMM	WB0E/B	10129.1 CW BCN	2 dB	19 wpm	1549z 22 Jun

**RBN**

[reversebeacon.net](http://reversebeacon.net)

**WSPRnet**

Welcome to the Weak Signal Propagation Reporter Network

Activity | Map | Database | Stats | Forum | Downloads

User login

Username \*

Password \*

Log in

Spot Count

695 805,353 total spots

698,973 in the last 24 hours

35,721 in the last hour

**WSPRNet**

[wspnet.org](http://wspnet.org)

**PSKReporter**

On all bands show signals sent/received by the call sign using all modes over the last 12 hours

Automatic refresh in 5 minutes. Large markers are monitors.

There are 1763 active monitors: 165 on 20m, 157 on 40m, 185 on 75m, 76 on 15m, 51 on 30m, 22 on 10m, 15 on 11m, 9 on unknown, 6 on 12m, 5 on 80m, 4 on 60m, 3 on 200m, 3 on 2m, 2 on 70cm, 2 on 23cm, 1 on 60cm

Monitor: W4QWHE Loc EN16pu in United States

Receiving: PSK31 JT65 on 14.070 MHz (20m)

Using: Digital Master 780 6.4.0.647/Rgr-V0.6

Antenna: (http://myantennas.com/wp/) 80-10m OCF dipole or Comtek 40m ver

Show all seen by W4QWHE

**PSKReporter**

[pskreporter.info](http://pskreporter.info)

## Observations from 21 August 2017 1400 – 2200 UT

Network	# Spots / QSOs
RBN	618,623
WSPRNet	630,132
PSKReporter	1,287,962
Participant Logs	29,809

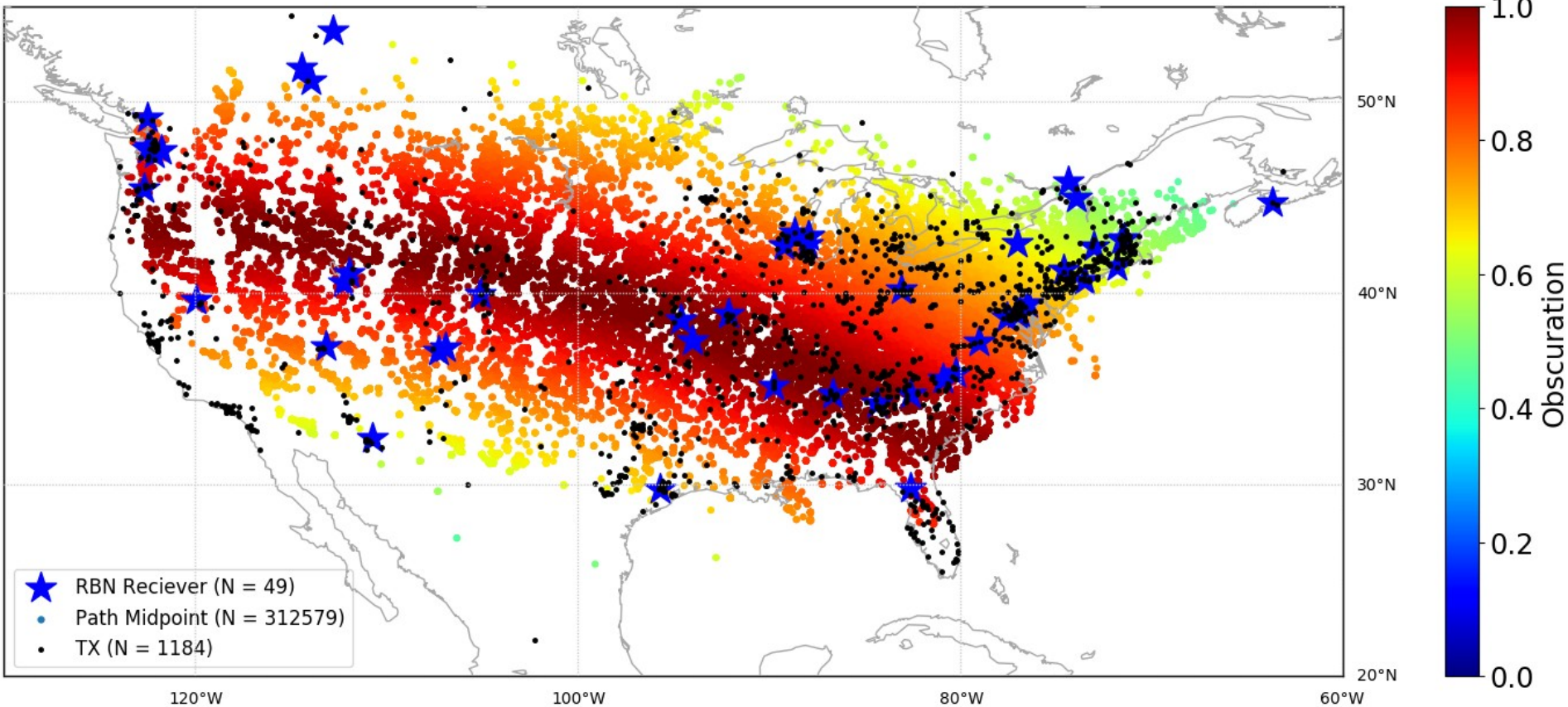
# Ham Radio Eclipse Data

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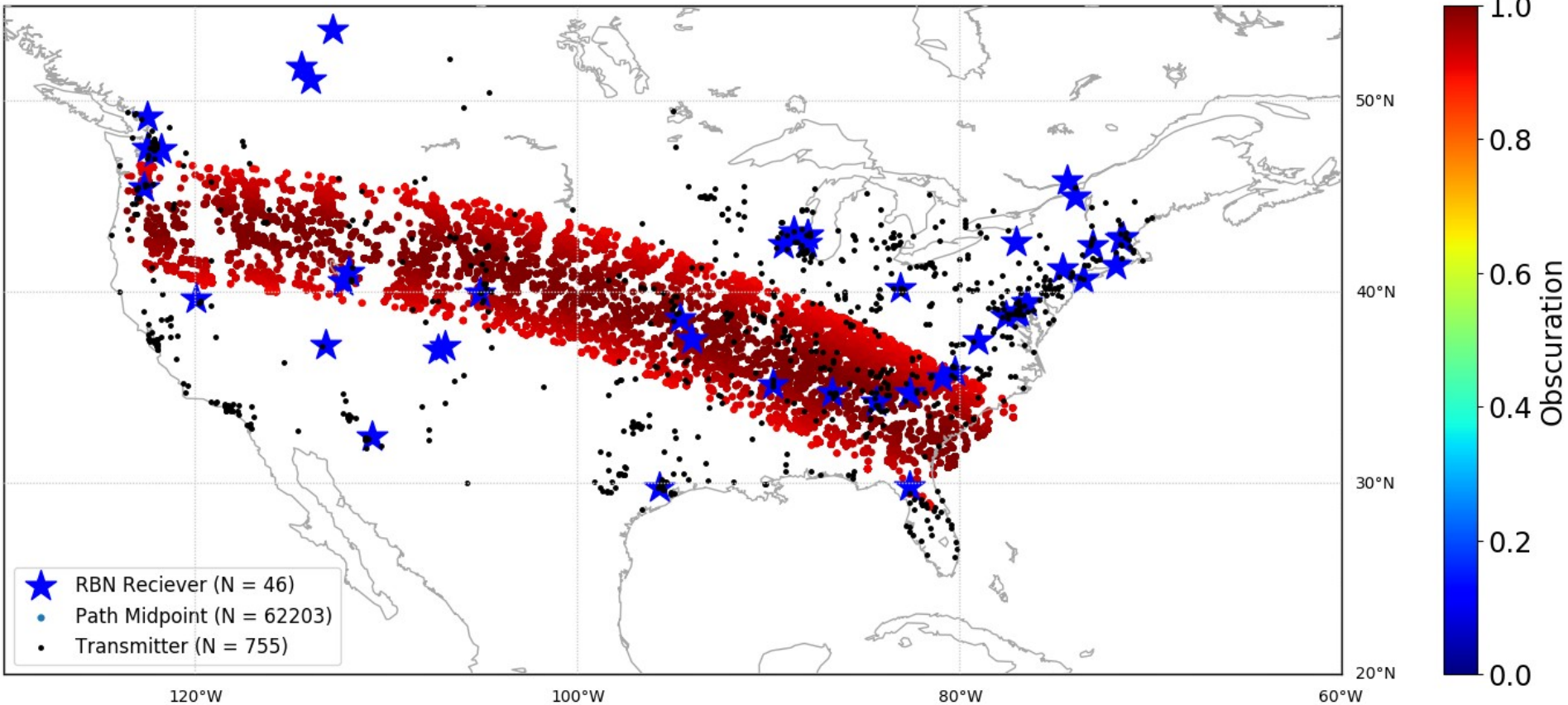




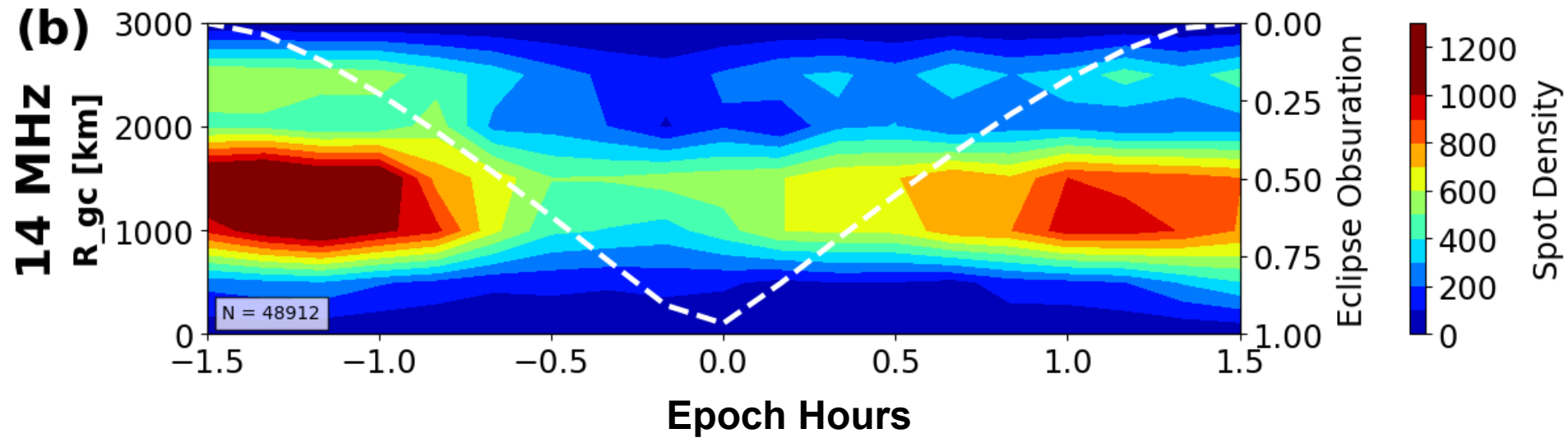
# SEQP RBN Observations



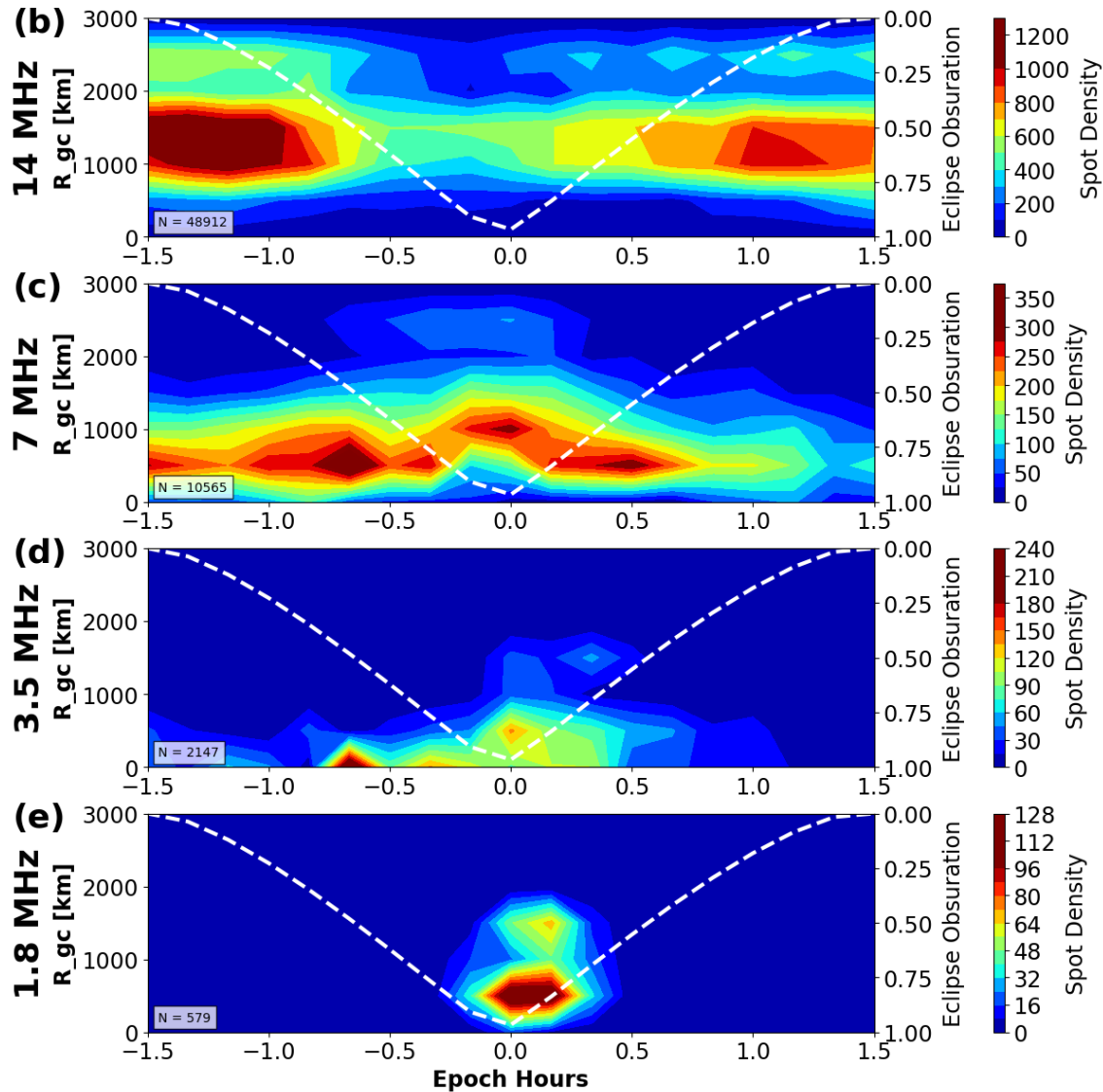
# SEQP RBN ( $O_{300} \geq 0.9$ )



# 14 MHz SEQP RBN ( $O_{300} \geq 0.9$ )



# SEQP RBN ( $O_{300} \geq 0.9$ )





# SAMI3 Eclipsed Model Ionosphere

AGU PUBLICATIONS

Geophysical Research Letters

RESEARCH LETTER

10.1002/2017GL073549

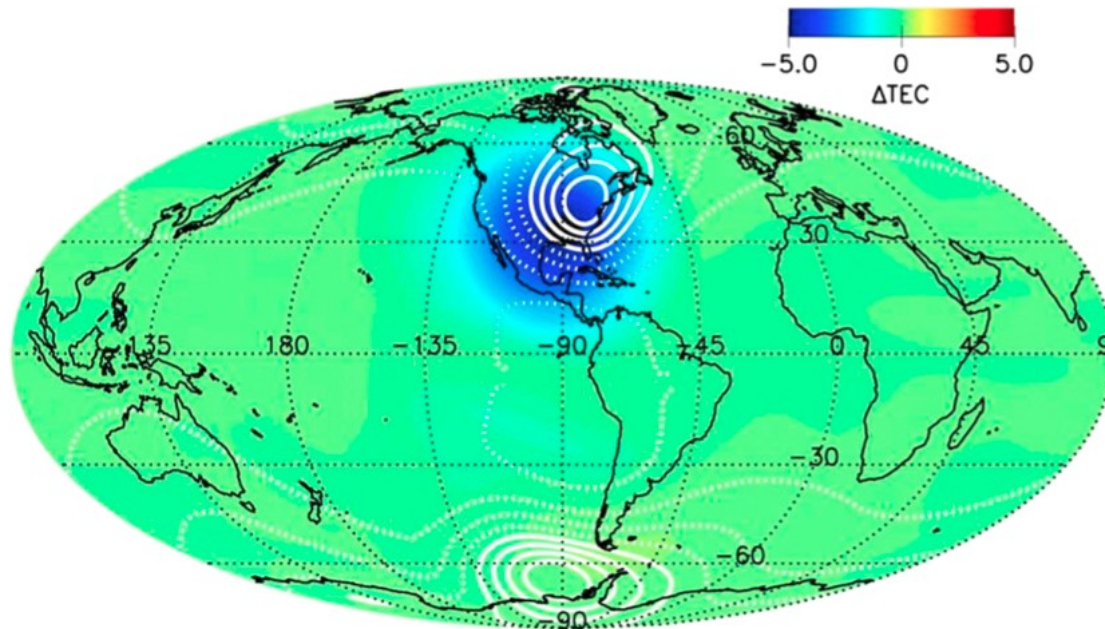
**Key Points:**

- Solar eclipse will reduce the electron density in the F region by up to a factor of 2
- The electron temperature in the plasmasphere will decrease by up

SAMI3 prediction of the impact of the 21 August 2017 total solar eclipse on the ionosphere/plasmasphere system

J. D. Huba<sup>1</sup> and D. Drob<sup>2</sup>

<sup>1</sup>Plasma Physics Division, Naval Research Laboratory, Washington, District of Columbia, USA, <sup>2</sup>Space Science Division, Naval Research Laboratory, Washington, District of Columbia, USA



Huba and Drob [2017]

- SAMI3 is a first-principles ionosphere/plasmasphere model.
- A modified version of SAMI3 was made to predict the ionospheric response to the eclipse.
- SEQP results were simulated by using the PHaRLAP HF raytracing toolkit [Cervera and Harris, 2014] in conjunction with the eclipsed SAMI3 model.



# SAMI3-PHaRLAP Raytrace

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1600 – 2200 UT 14.03 MHz

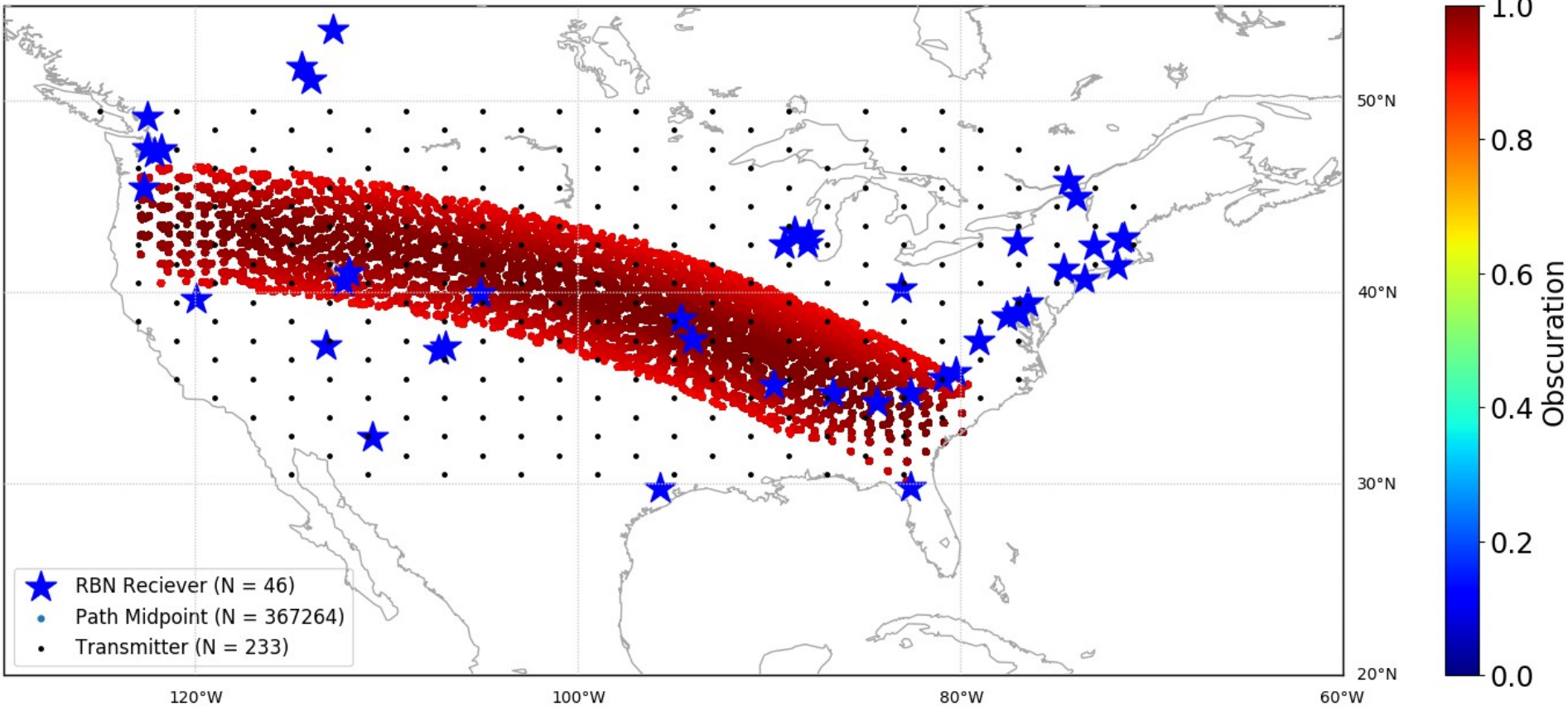
TX: AA2MF (Florida) RX: WE9V (Wisconsin)

Non-Eclipsed

Eclipsed

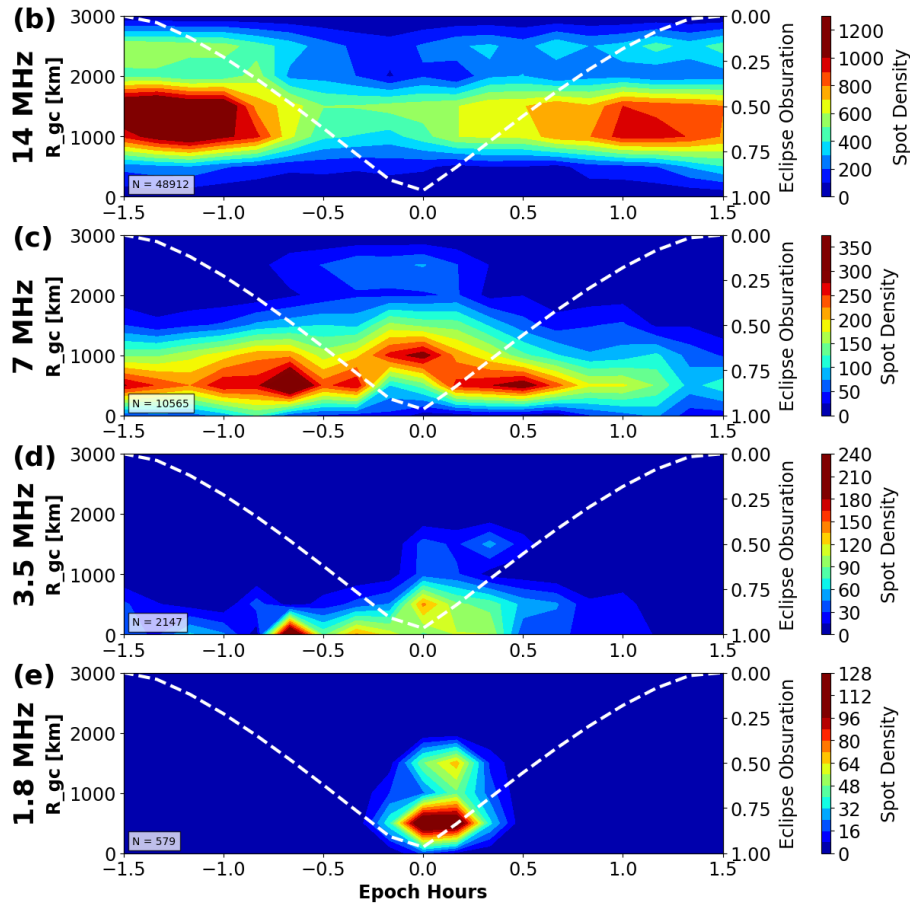


# SAMI3-PHaRLAP ( $O_{300} \geq 0.9$ )

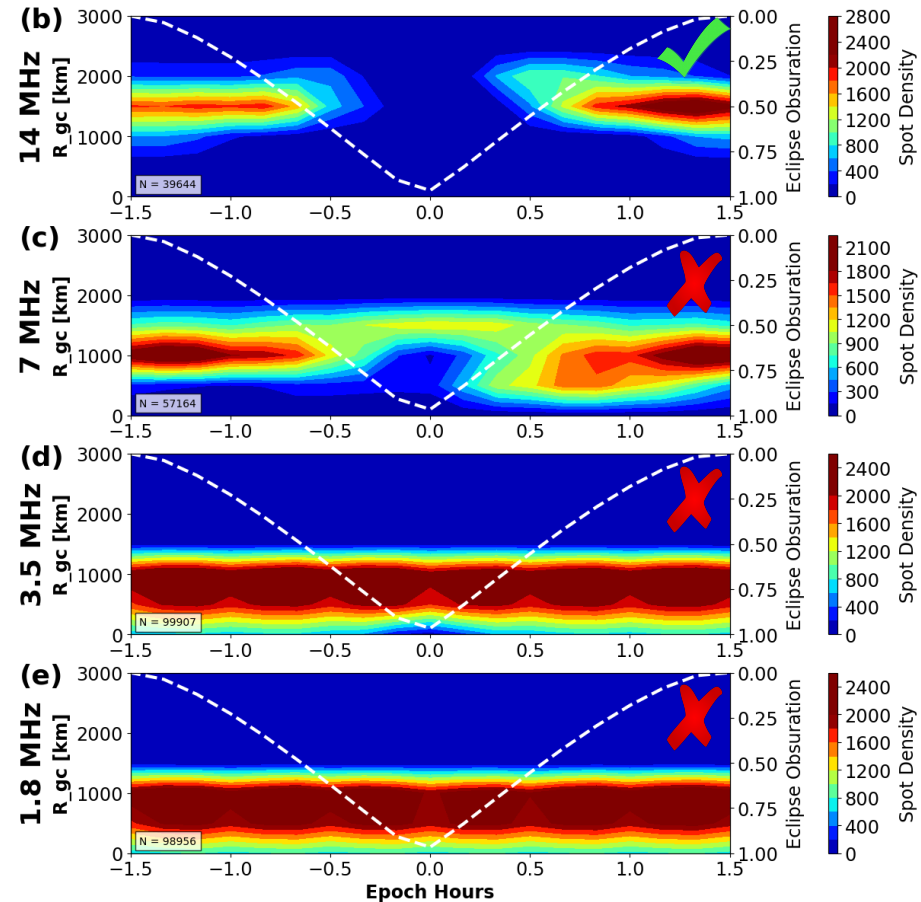


# SAMI3 < 125 km alt

## RBN Observations

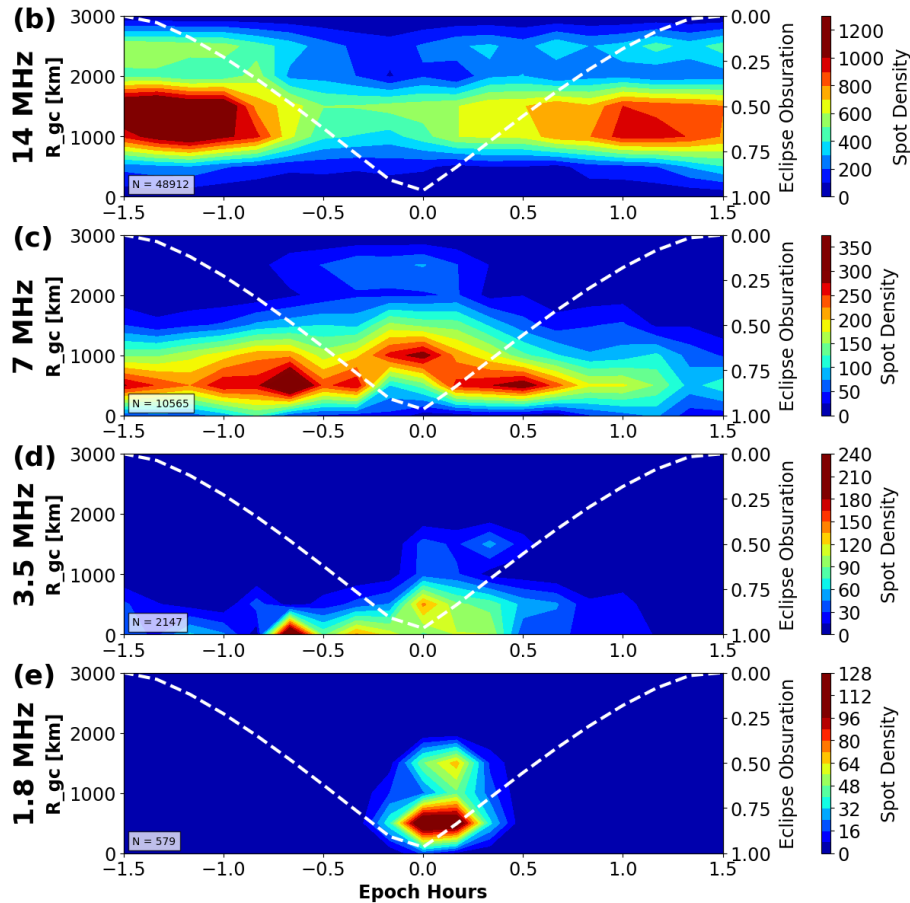


## SAMI3 < 125 km Altitude

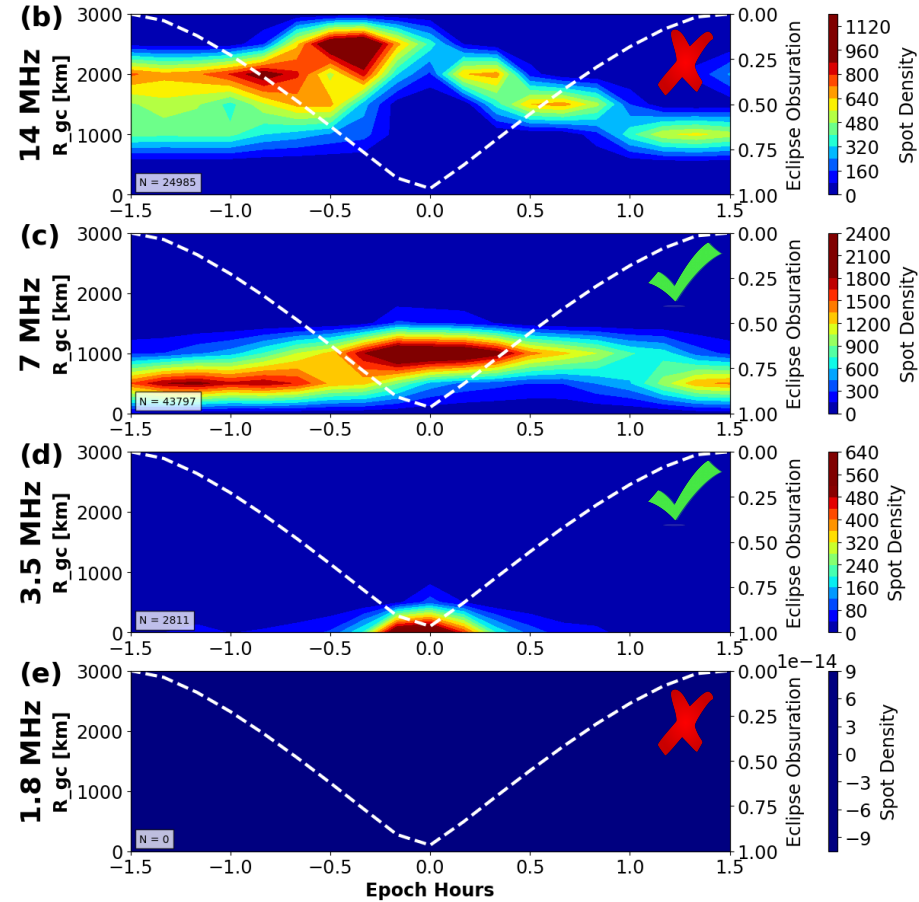


# SAMI3 $\geq 125$ km alt

## RBN Observations



## SAMI3 $\geq 125$ km Altitude

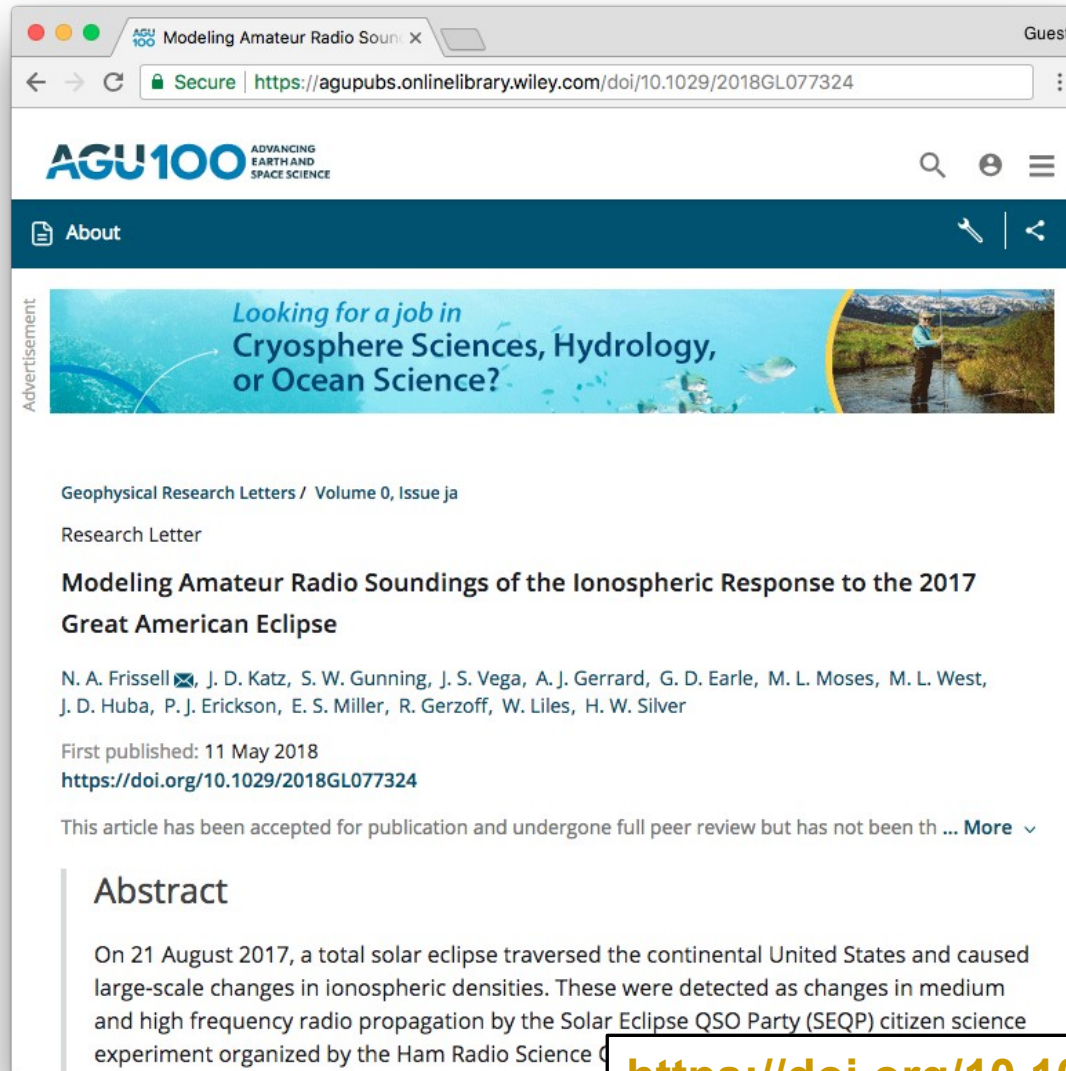


# Conclusions

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- SEQP generated over 2.5 million link soundings.
- Eclipse effects are observed:
  - $\pm 0.3$  hr on 1.8 MHz
  - $\pm 0.75$  hr on 3.5 and 7 MHz
  - $\pm 1$  hr on 14 MHz
- Raytracing suggests:
  - 14 MHz signals refracted at  $h < 125$  km
  - 1.8 - 7 MHz refracted at  $h \geq 125$  km altitude
  - Background SAMI3 density slightly too high

# Published in Geophysical Research Letters!



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Geophysical Research Letters / Volume 0, Issue ja

Research Letter

**Modeling Amateur Radio Soundings of the Ionospheric Response to the 2017 Great American Eclipse**

N. A. Frissell ✉, J. D. Katz, S. W. Gunning, J. S. Vega, A. J. Gerrard, G. D. Earle, M. L. Moses, M. L. West, J. D. Huba, P. J. Erickson, E. S. Miller, R. Gerzoff, W. Liles, H. W. Silver

First published: 11 May 2018  
<https://doi.org/10.1029/2018GL077324>

This article has been accepted for publication and undergone full peer review but has not been th ... **More** ▾

**Abstract**

On 21 August 2017, a total solar eclipse traversed the continental United States and caused large-scale changes in ionospheric densities. These were detected as changes in medium and high frequency radio propagation by the Solar Eclipse QSO Party (SEQP) citizen science experiment organized by the Ham Radio Science C

<https://doi.org/10.1029/2018GL077324>

# Single Operator (Preliminary)

---

Call Sign	Phone QSOs	CW/Dig QSOs	Grids	Bonus	Total
<b>AA3B</b>					
1 Bud Trench Boyertown, PA	0	680	296	1,415	403,975
<b>K4BAI</b>					
2 John Laney, III Columbus, GA	0	451	248	806	224,502
<b>W1SJ</b>					
3 Mitchell Stern Essex Junction, VT	163	313	228	990	180,882



# Multi Operator (Preliminary)

---

Call Sign	Phone QSOs	CW/Dig QSOs	Grids	Bonus	Total
<b>W0ECC</b> Elayer Contest Club 1 St. Charles, MO (N0AX, N5OT, & KD0YJN)	409	50	220	665	191,625
<b>W0D</b> 2 DeSoto, MO (WB0SND & WB0TUA)	352	26	153	863	112,553
<b>W5GAD</b> 3 Jefferson Amateur Radio Club Metairie, LA (N5LIT, KG5GJT, N5HZ, & NO5W)	256	45	167	632	93,651



# SEQP RBN 10,000+ Club

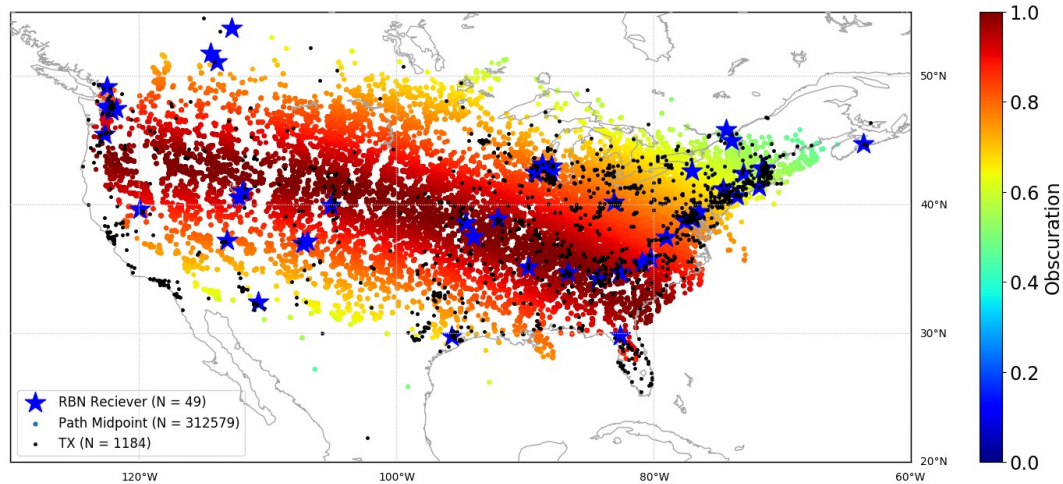
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RBN Call	# Spots	Operator	QTH
<b>WE9V</b>	54,874	Chad Kurszewski	Bristol, WI
<b>AA4VV</b>	40,574	Thomas Berry	Lexington, NC
<b>KU7T</b>	31,762	Andreas Hofmann	North Bend, WA
<b>N4ZR-3</b>	28,692	Pete Smith	Phoenix, MD
<b>NC7J</b>	28,564	Utah Contest Club	Layton, UT
<b>W3OA</b>	28,057	Dick Williams	Mooreville, NC
<b>N2GZ</b>	18,623	Greg Zenger	North Stonington, CT
<b>N0TA</b>	14,751	John Reilly	Loisville, CO

# Special Thanks

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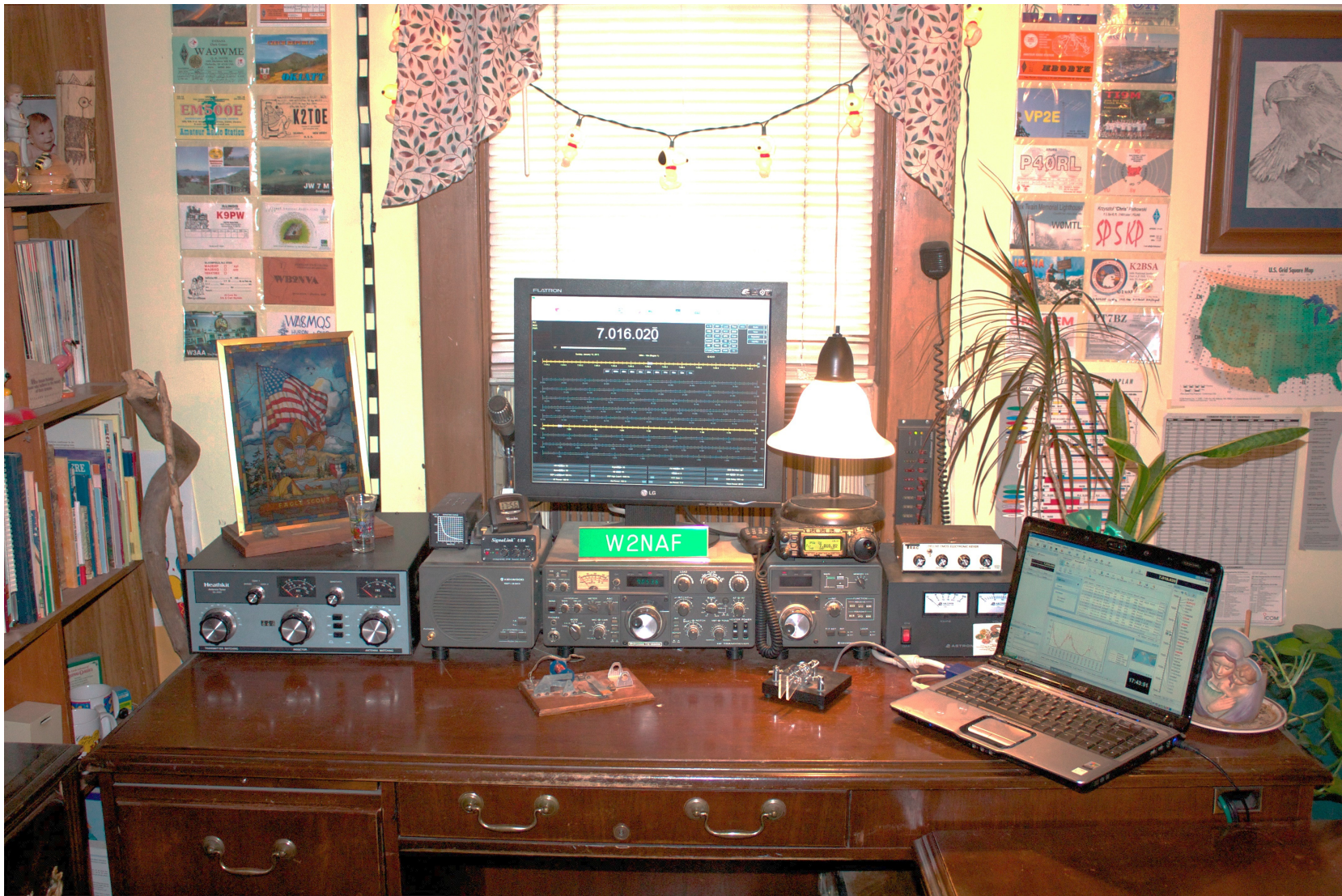
- John Ackermann, N8UR
- David Bern, W2LNX
- Terry Bullett, W0ASP
- Felipe Ceglia, PY1NB
- Greg Earle, W4GDE
- Bill Engelke, AB4EJ<sup>2</sup>
- Phil Erickson, W1PJE
- Rachel Frissell, W2RUF
- Andy Gerrard, KD2MCQ
- Bob Gerzoff, WK2Y
- Spencer W. Gunning, K2AEM
- Michael Hirsch, N2NRL
- Steve Kaepler, ADOAE
- Joshua D. Katz, KD2JAO
- John Magliacane, KD2BD
- Bob McGwier, N4HY
- Ethan Miller, K8GU
- Magda Moses, KM4EGE
- Carl Luetzelschwab, K9LA
- Steve Reyer, WA9VNJ
- Sam Rose, KC2LRC
- Alex Shovkoplyas, VE3NEA
- Ward Silver, N0AX
- Pete Smith, N4ZR
- Pete Teklinski, WW2I
- Joshua S. Vega, WB2JSV
- Mary Lou West, KC2NMC
- Dick Williams, W3OA
- The ARRL*
- All hams who have participated in HamSCI projects.*



# Thank you!



# Amateur/Ham Radio





# Total Solar Eclipse

21 August 2017

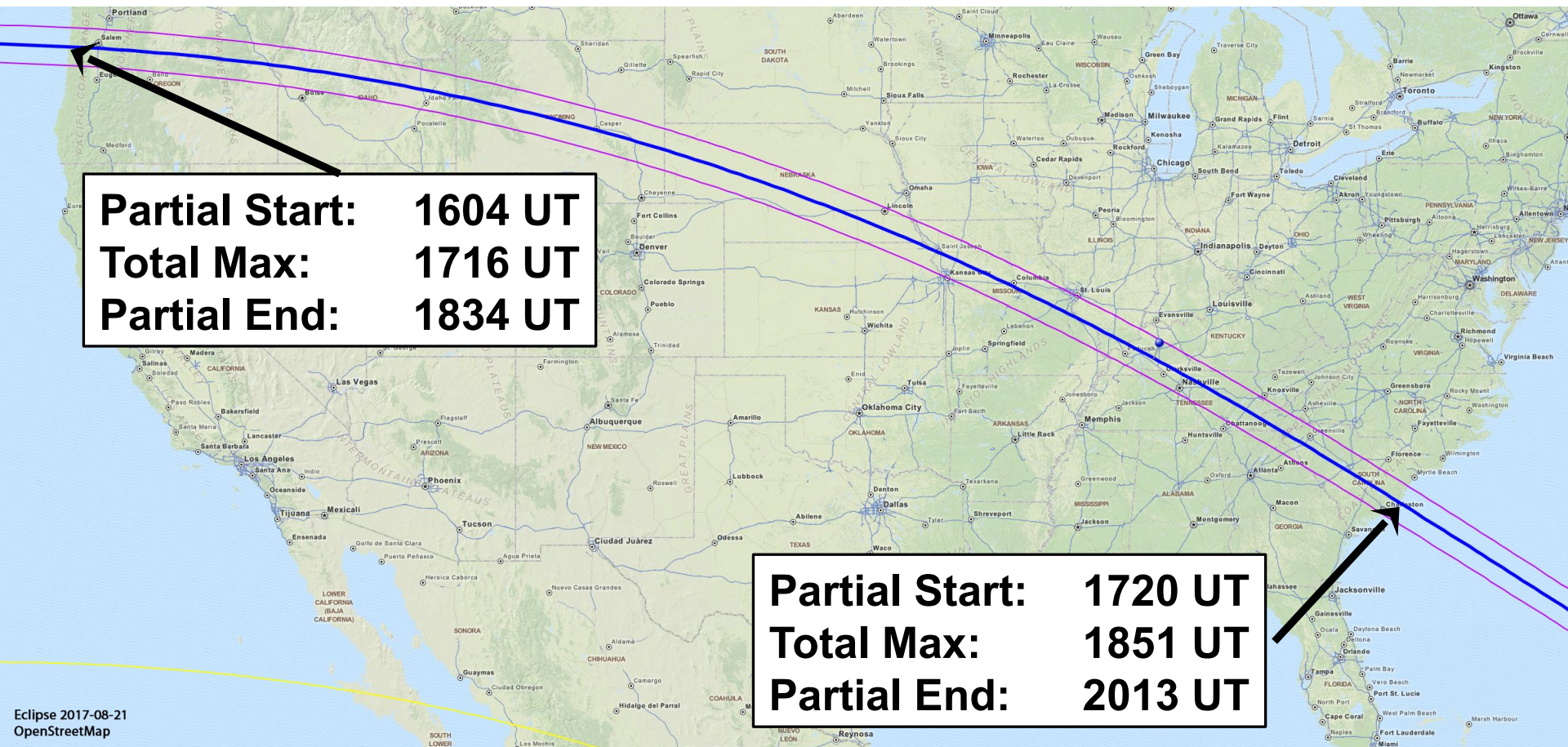
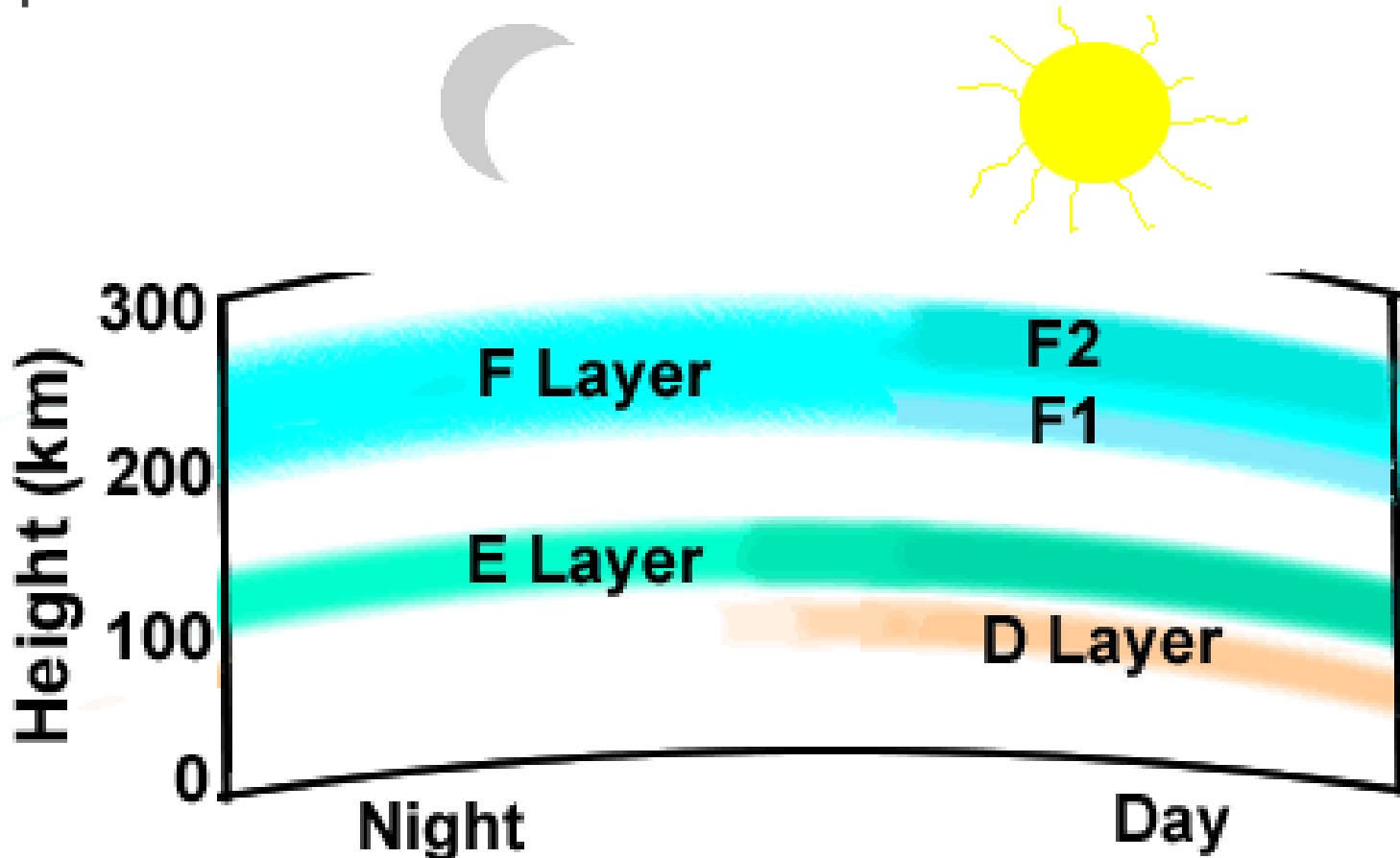


Figure: W. Strickling, Wikipedia



# What is the Ionosphere?

- Primarily created by ionization of the neutral atmosphere by solar UV radiation



<https://commons.wikimedia.org/wiki/File:IonosphereLayers-NPS.gif>

# Ionospheric Effects?

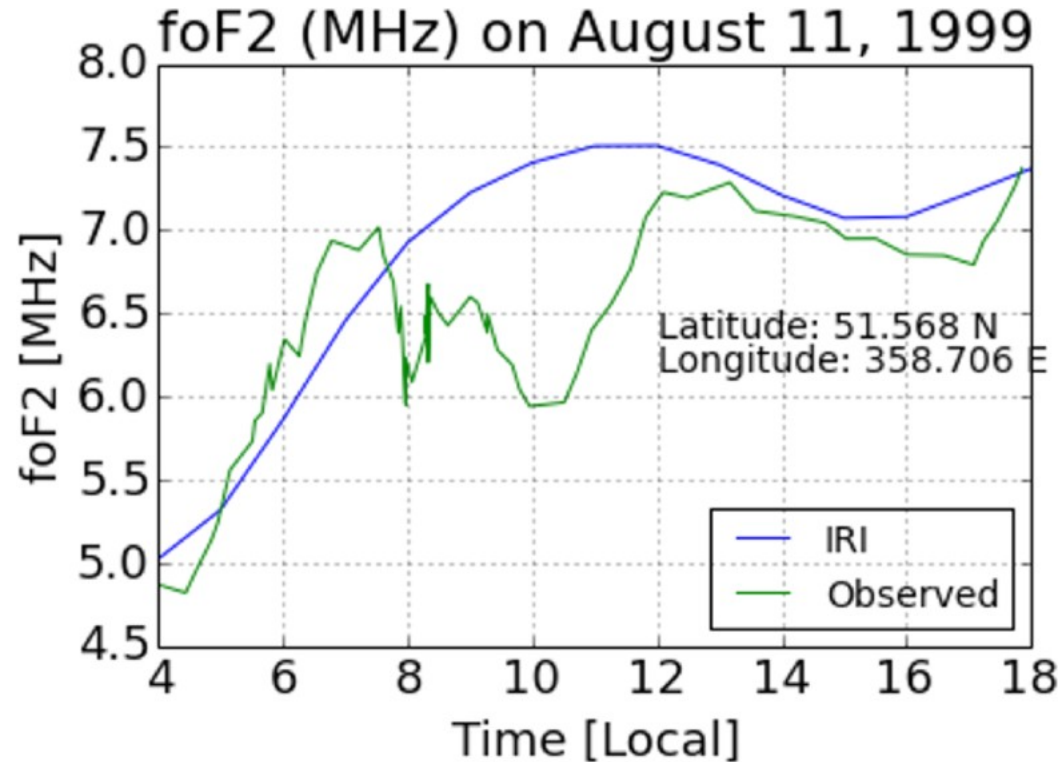
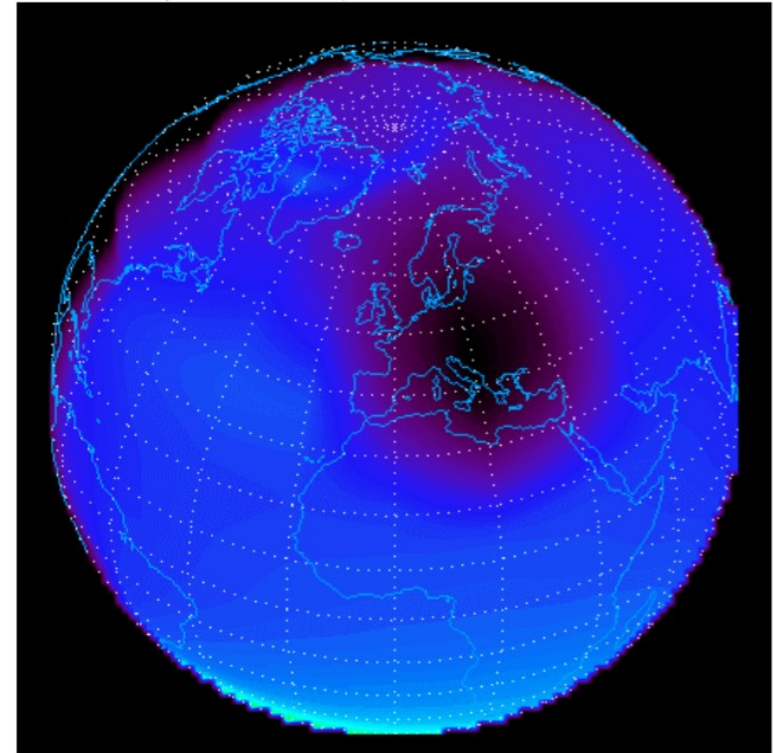
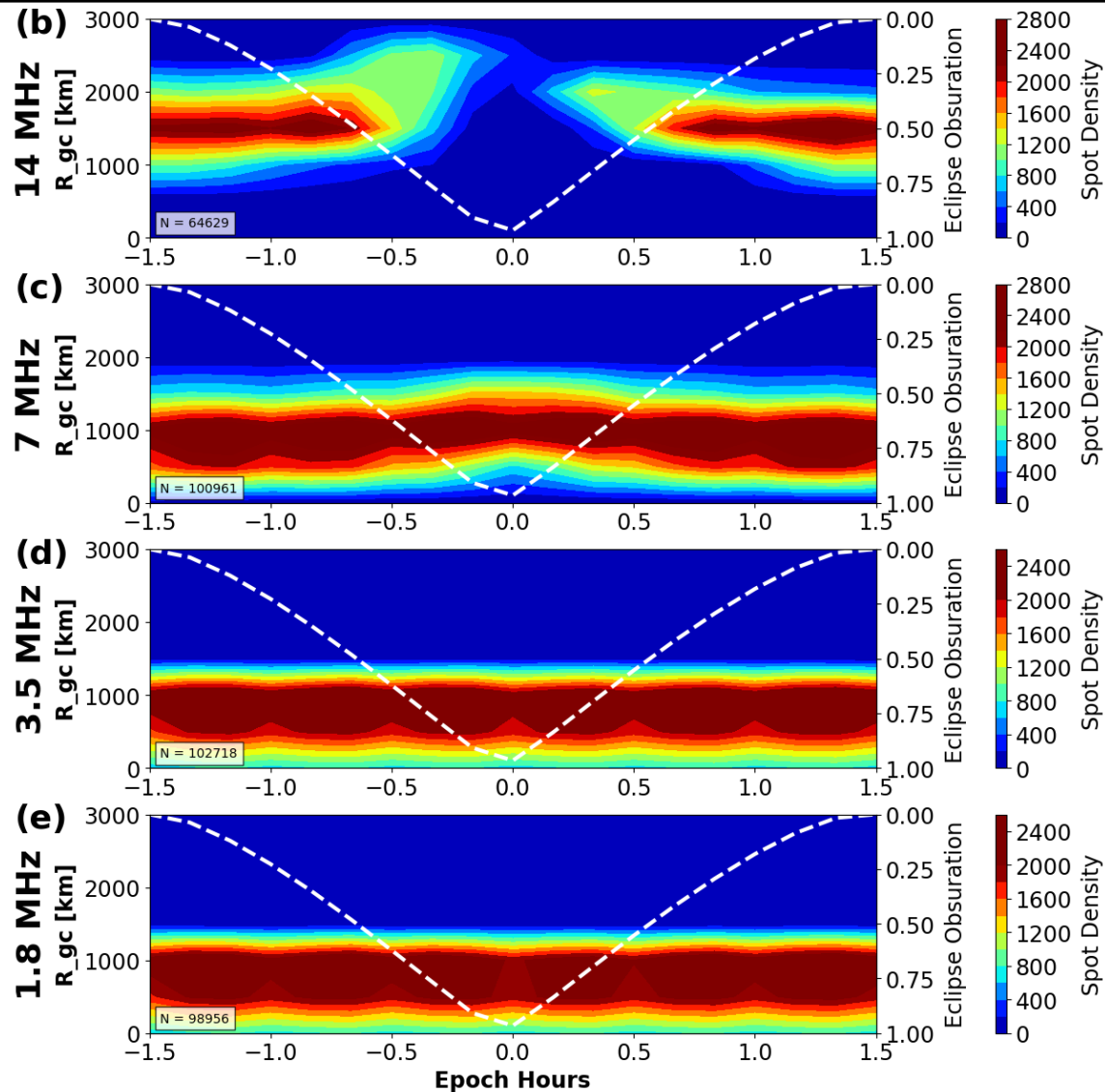


Figure: M. Moses



Model Electron Density at ~280 km alt. during 1999 Eclipse  
M. Harris from *Bamford* 2000.

# Eclipsed SAMI3 - PHaRLAP



# What does this mean? (14 MHz)

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- **Poor agreement with  $h \geq 125$  km altitude**
  - Ionosphere is always too weak to support 14 MHz high-angle signals.
- **Good agreement with  $h < 125$  km altitude.**
  - Before eclipse, low angle 14 MHz signals were below the critical angle for E Region ionosphere and would refract back to earth.
  - 14 MHz signals are relatively unaffected by D region absorption.
  - At high obscuration values, ionospheric densities drop such that neither the E nor the F region can support 14 MHz.

# SAMI3-PHaRLAP Raytrace

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1600 – 2200 UT 14.03 MHz  
TX: AA2MF (Florida) RX: WE9V (Wisconsin)  
Eclipsed SAMI3





# What does this mean? (1.8 – 7 MHz)

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- **Poor agreement with  $h < 125$  km altitude**
  - Low angle signals spend more time in the D region
  - D region absorbs 1.8 – 7 MHz signals
  - All low-angle signals get absorbed.
- **Good agreement with  $h \geq 125$  km altitude.**
  - Higher angle rays suffer less D region absorption.
  - 1.8 & 3.5 MHz signals only appear near maximum eclipse, when D region absorption is minimal.
  - 7 MHz signals are always present, but extend in range as ionospheric densities and associated refraction decreases

# References

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**Afraimovich, E.L.,** E.A. Kosogorov, O.S. Lesyuta (2002), Effects of the August 11, 1999 total solar eclipse as deduced from total electron content measurements at the GPS network, Journal of Atmospheric and Solar-Terrestrial Physics, Volume 64, Issue 18, Pages 1933-1941, ISSN 1364-6826, [http://dx.doi.org/10.1016/S1364-6826\(02\)00221-3](http://dx.doi.org/10.1016/S1364-6826(02)00221-3).

**Bamford, R.** (2000), Radio and the 1999 UK Total Solar Eclipse, Rutherford Appleton Laboratory, Chilton, Didcot, UK.

# Calibrate the model?

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- Data-model comparison suggests critical frequency of the model is too high, due to incorrect predictions of:
  - High-angle 14 MHz returns
  - Low-angle 1.8 MHz returns
- It may be possible to calibrate the model by scaling SAMI3 electron densities to best fit the observed data.

# Outline

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## I. Ham Radio and HamSCI

## II. Solar Eclipse QSO Party

I. Ham Radio Observations

II. Modeling Results

III. Discussion

IV. Conclusions

# Amateur/Ham Radio

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- Hobby for Radio Enthusiasts
  - Communicators
  - Builders
  - Experimenters
- Wide-reaching Demographic
  - All ages & walks of life
  - Over 730,000 US hams; ~3 million World Wide

[<http://www.arrl.org/arrl-fact-sheet>]





# Partnership with ARRL

## American Radio Relay League

- National Organization for Ham Radio
  - Over 170,000 members (Jan. 2016)
  - Monthly magazine
  - Publishes over 160 books
  - Strong web/social media presence
  - Education/Outreach Program
- 
- Promoted HamSCI and 2017 Eclipse QSO Party



August 2016 QST

HamSCI  
<http://hamsci.org>

NJIT

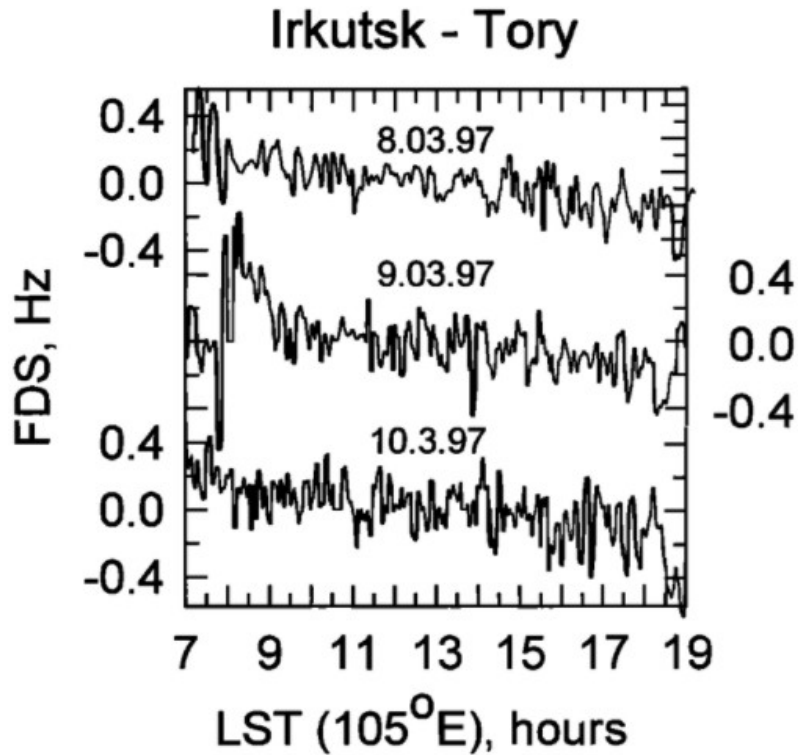
[frissell@njit.edu](mailto:frissell@njit.edu)

# Conclusions

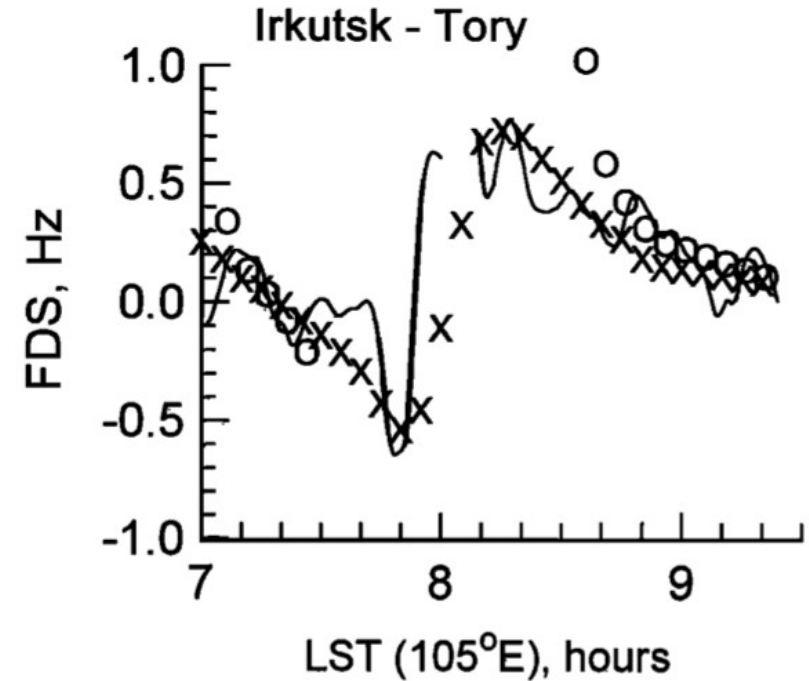
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- A ham radio experiment known as the Solar Eclipse QSO Party (SEQP) was conducted on August 21, 2017 to monitor changes in the ionosphere due to a total solar eclipse occurring over the continental United States.
- The SEQP sounded the ionosphere using ham radio contest-style operating and generated over 2.5 million link soundings. This constitutes perhaps the largest ionospheric citizen science dataset ever created.
- Observations on the 160 - 20 m (1.8 - 14 MHz) amateur radio bands show evidence of eclipse-induced ionospheric density reductions up to  $\pm 1$  hour maximum eclipse.
- Observations were simulated using the PHaRLAP raytracing toolkit in conjunction with the eclipsed SAMI3 ionospheric model.
  - 14 MHz signals refracted at  $h < 125$  km.
  - 1.8 - 7 MHz refracted at  $h \geq 125$  km altitude.
  - Data-model comparison can be beneficial for the calibration of ionospheric models and the physical interpretation of amateur radio data.

# Eclipse HF Doppler Measurements



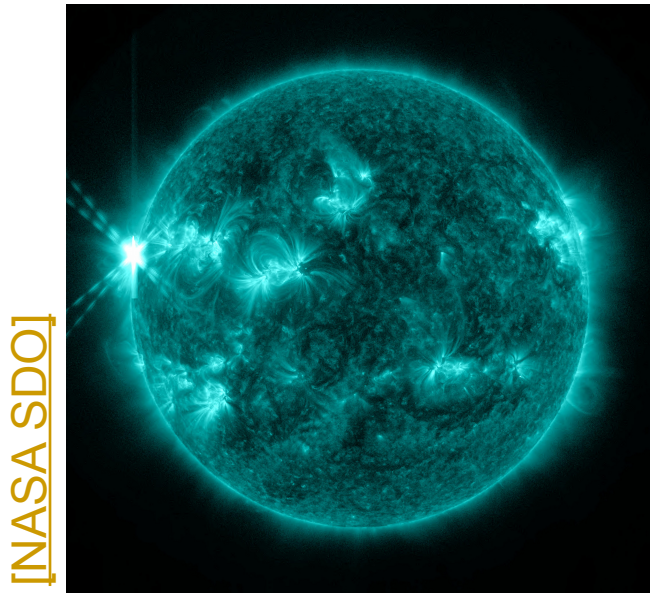
**Figure 6.** Temporary variations of frequency Doppler shift (FDS) recorded on the HF ray path Irkutsk - Tory during the daytime for March 8, 9, and 10, 1997.



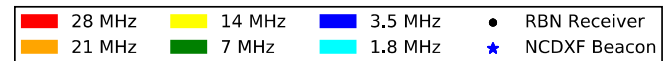
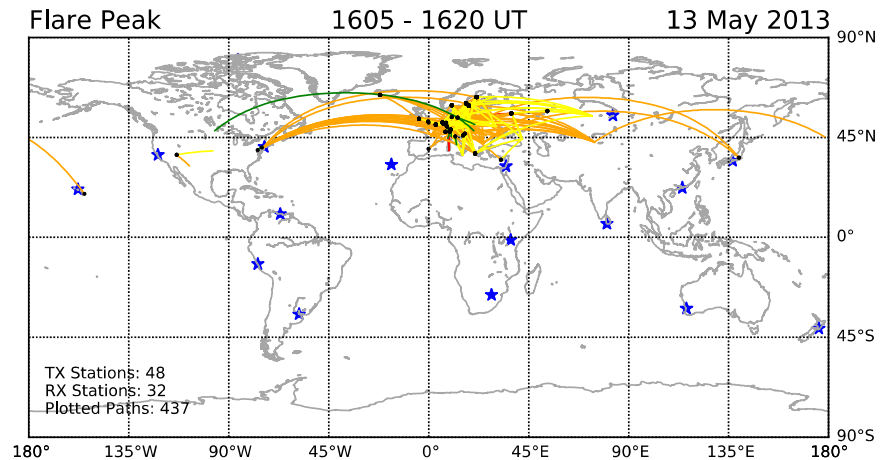
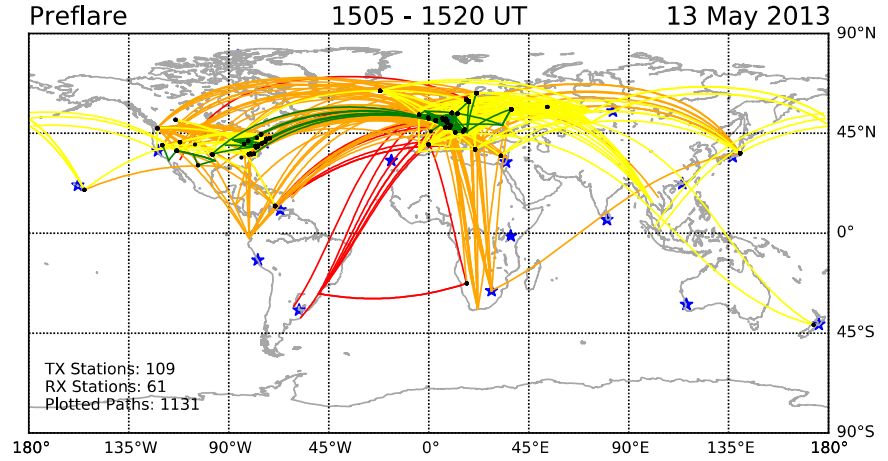
**Figure 7.** Comparison of measured (solid lines) and calculated temporary variations of frequency Doppler shift (FDS) during the eclipse on the HF ray path Irkutsk - Tory. Circles, calculation for the ordinary mode; crosses, calculation for the extraordinary mode.

[Boitman et al., 1999]

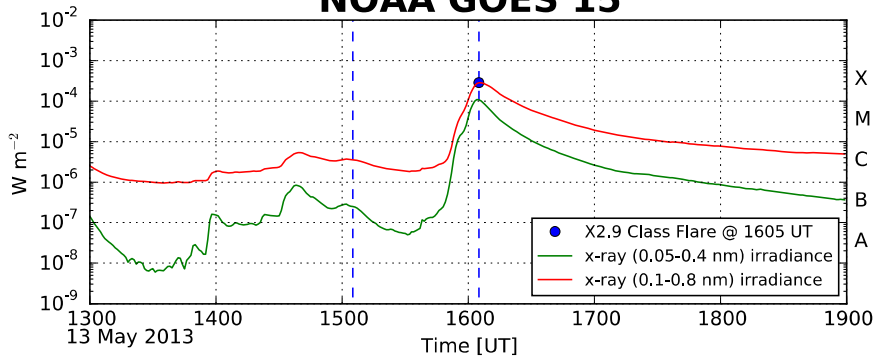
# Ham Radio and Space Weather



## Reverse Beacon Network Solar Flare HF Communication Paths



## NOAA GOES 15



[Frissell et al., 2014, Space Weather]

# Future Work

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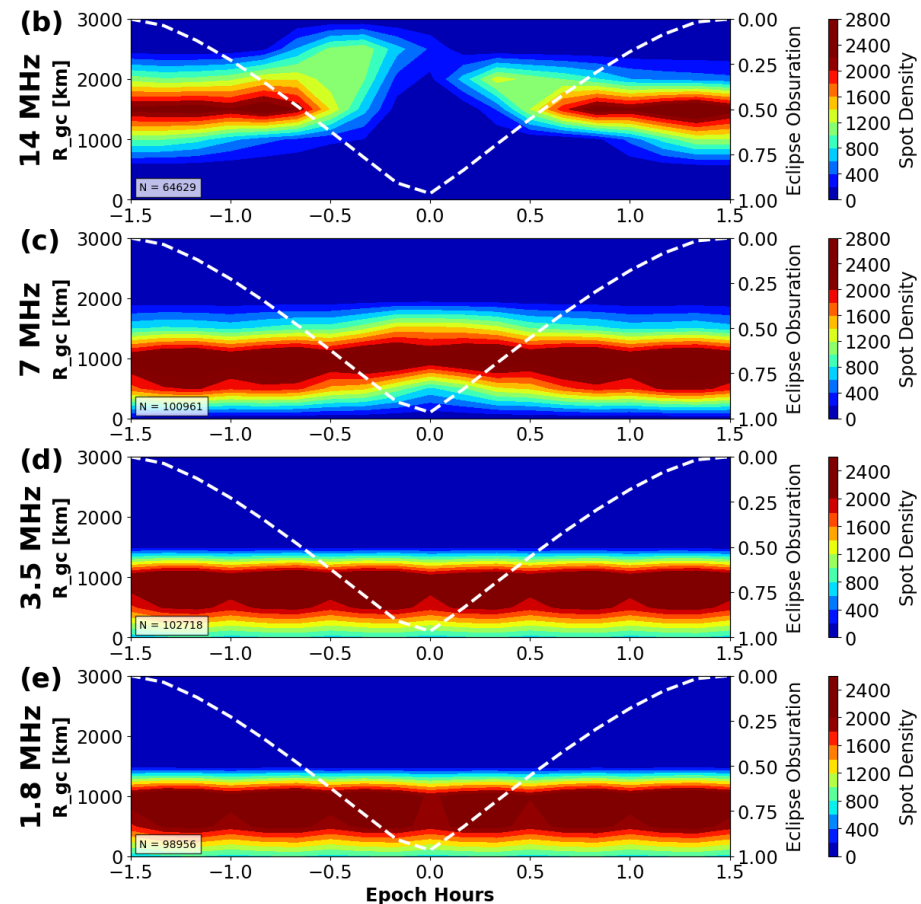
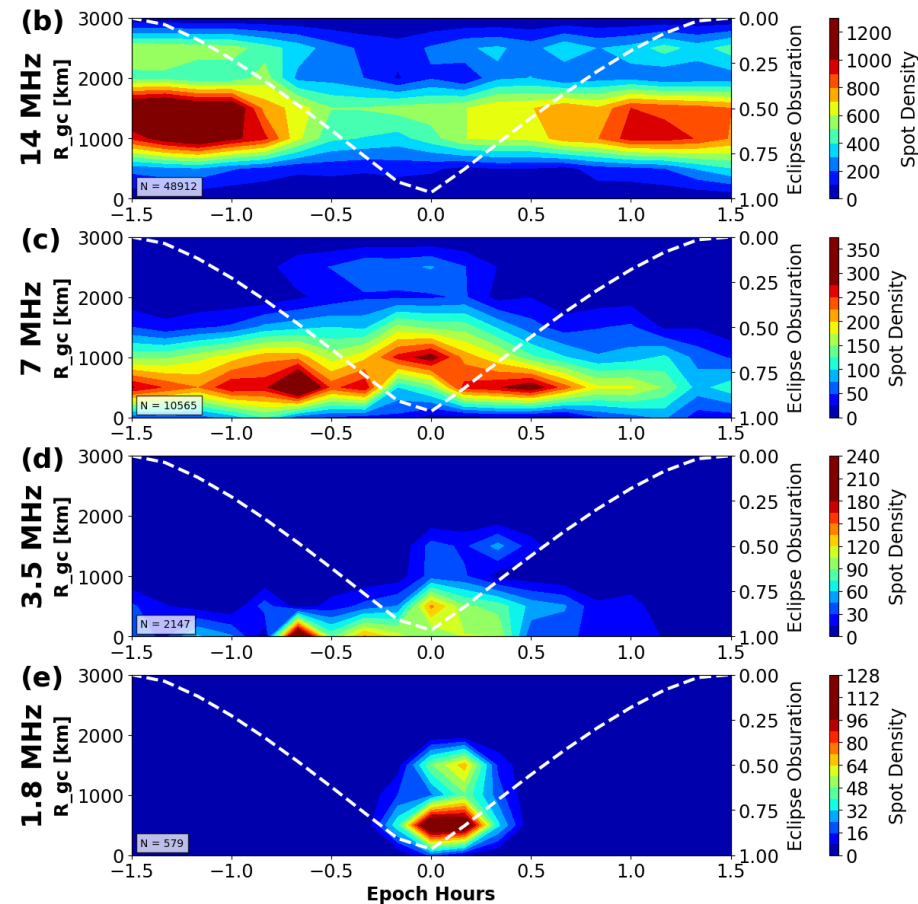
- Testing and validation of
  - Ray Trace Models
  - Ionospheric Models
- Development of new techniques for using ham radio data to characterize the ionosphere.
- Look for more localized eclipse effects?
  - Can we learn something new from the ionosphere?



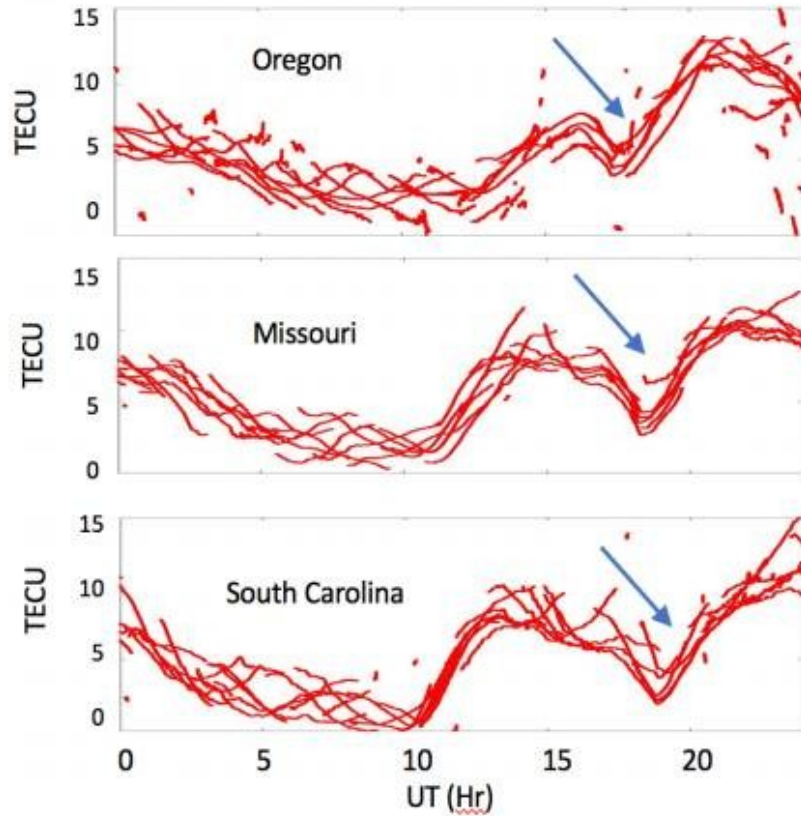
# RBN Observations – SAMI3 Simulation

## RBN Observations

## Eclipsed SAMI3 - PHaRLAP

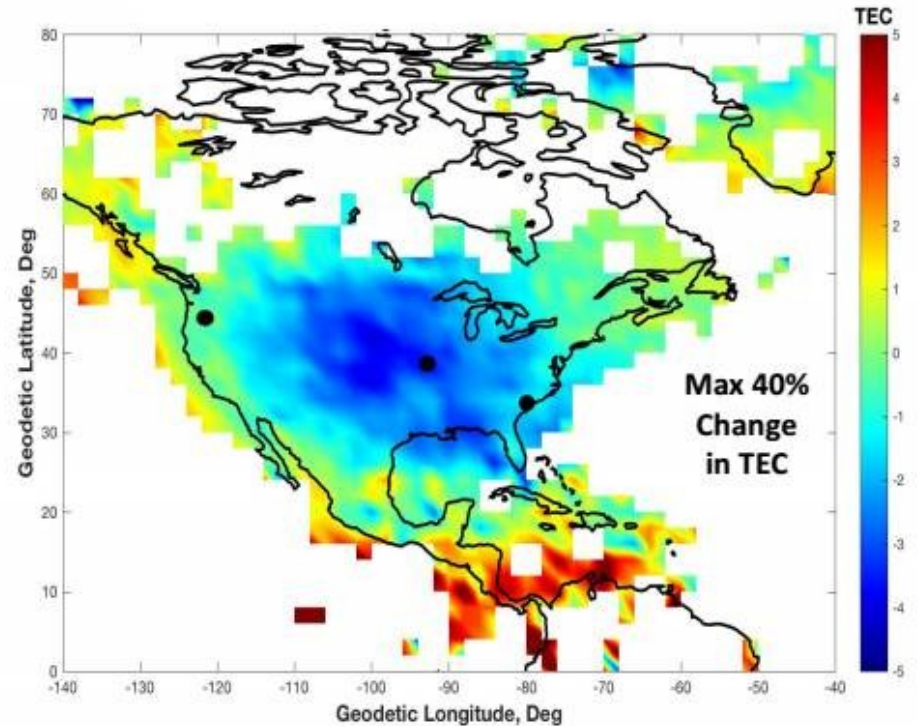


# GPS-TEC Observations



## Solar Eclipse GNSS Vertical Total Electron Content 21 August 2017

Difference in TEC at 18:15 UT from start of solar eclipse at 16:45 UT



Support: NSF AGS-1242204, NASA NNX17AH71G

*Courtesy of Anthea Coster*

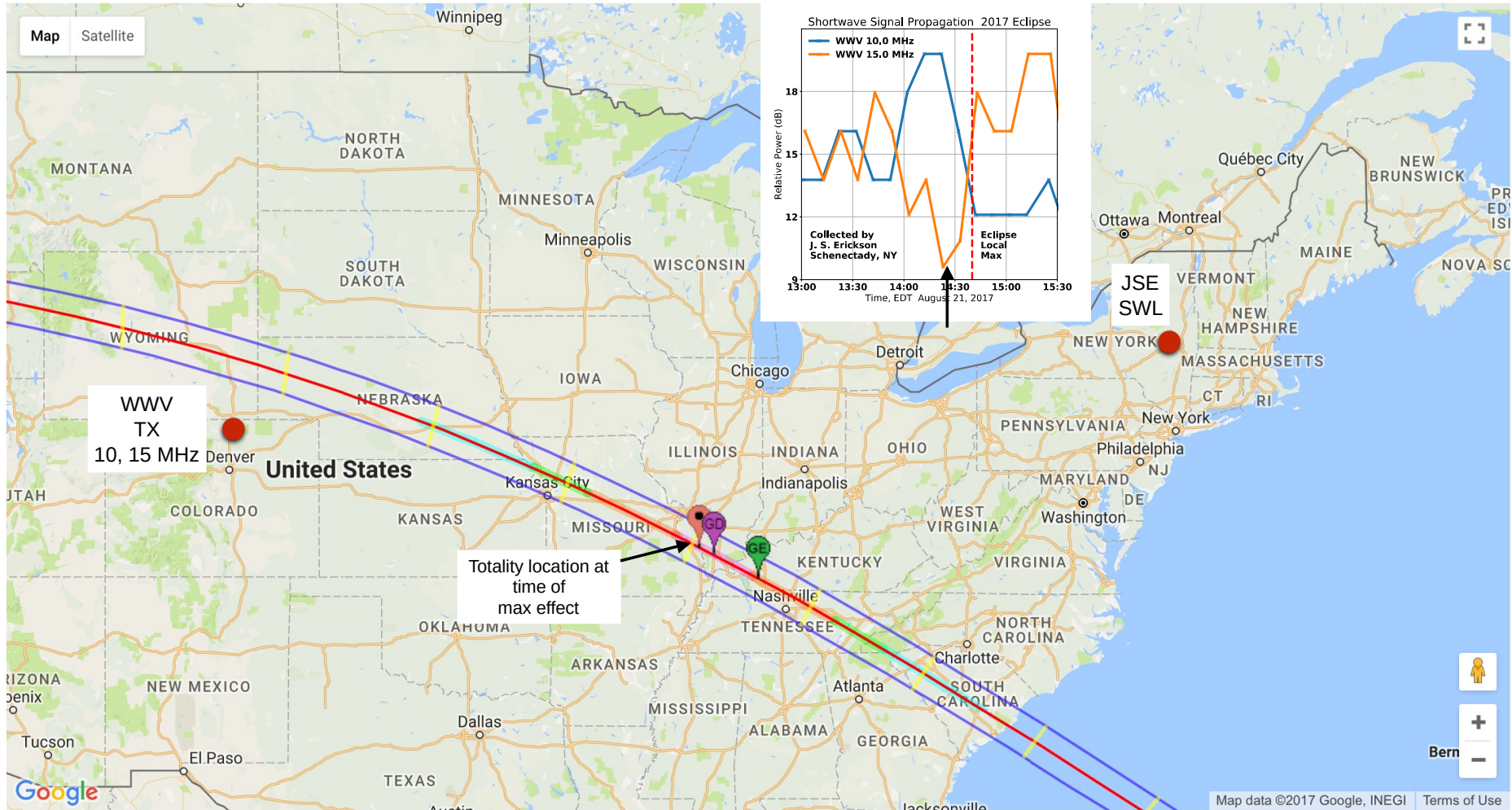
# GPS-TEC Observations



*Preliminary Results Courtesy of Anthea Coster, MIT Haystack*



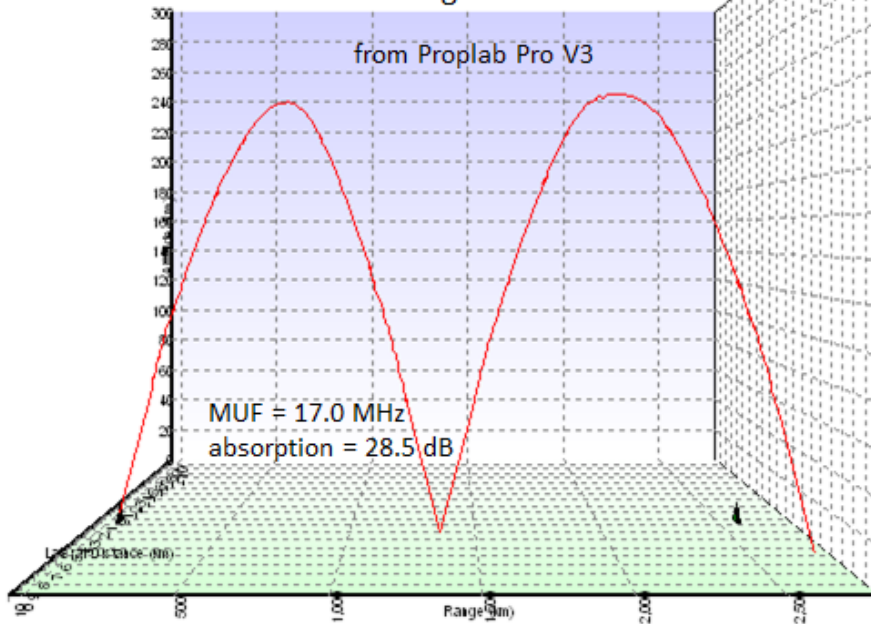
# 10 & 15 MHz WWV (Schenectady, NY)



# 10 & 15 MHz WWV (Schenectady, NY)

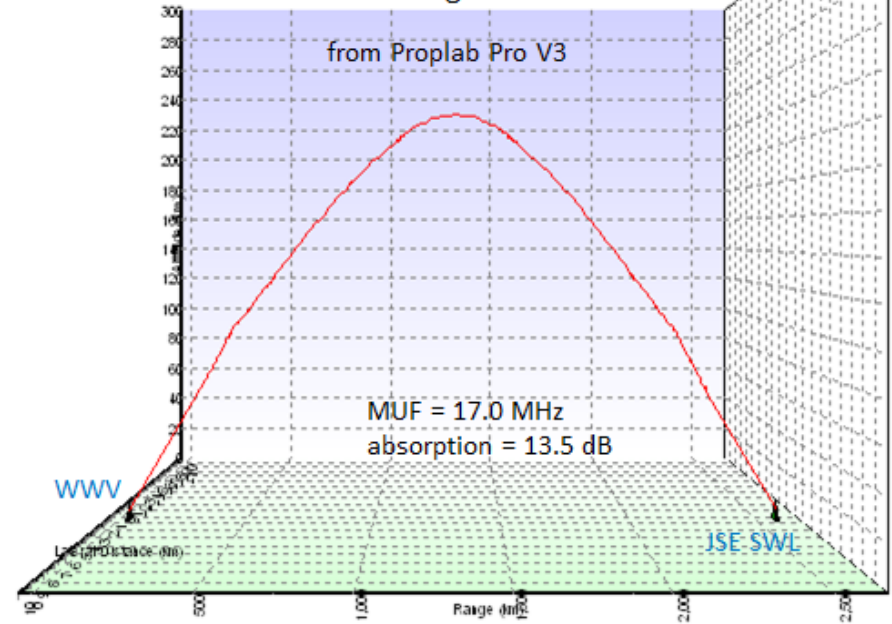
WWV 10.0 MHz to JSE SWL  
August 21, 2017 at 1830 UTC  
2618 km, o-wave  
elevation angle = 26.0°

from Proplab Pro V3



WWV 15.0 MHz to JSE SWL  
August 21, 2017 at 1830 UTC  
2618 km, o-wave  
elevation angle = 11.4°

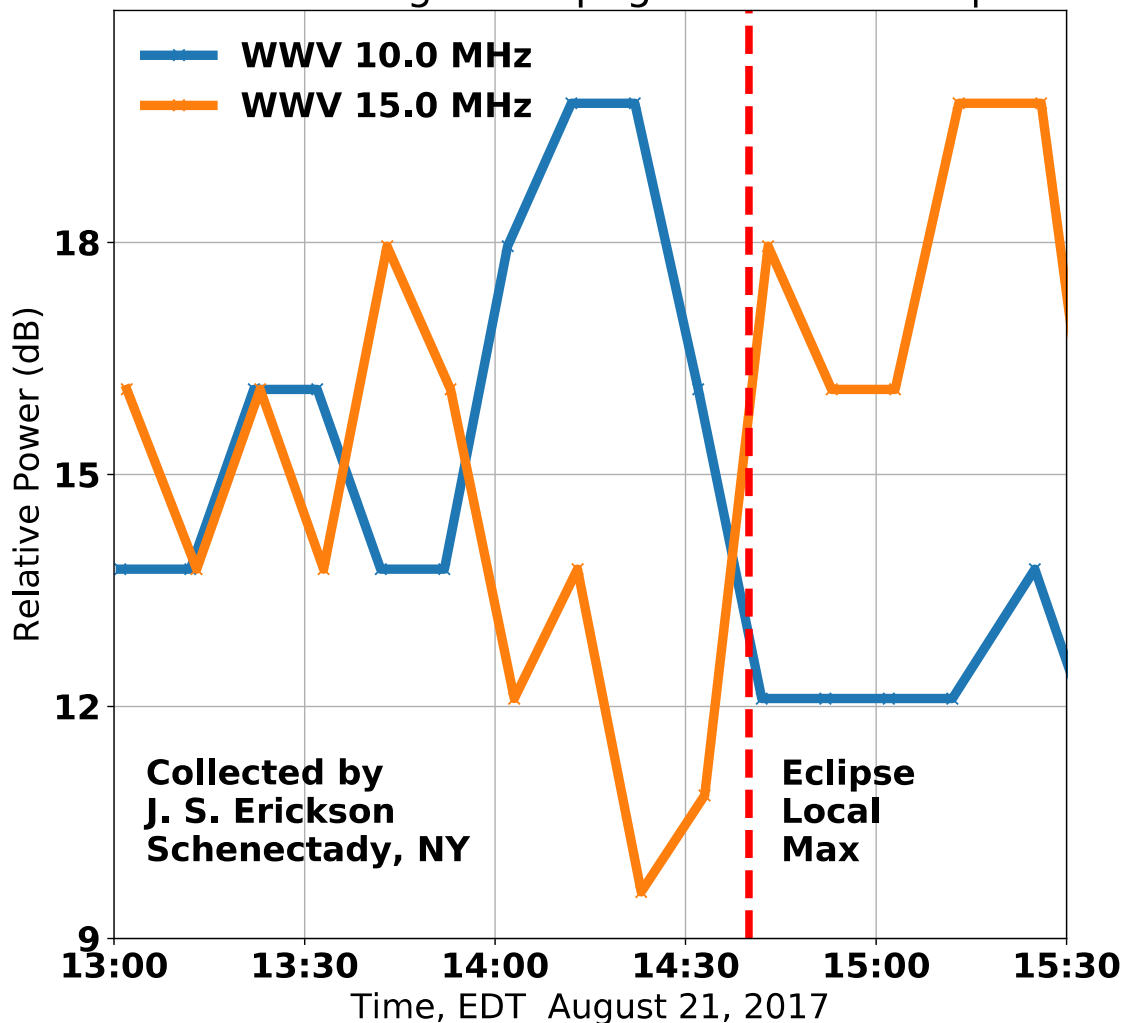
from Proplab Pro V3





# 10 & 15 MHz WWV (Schenectady, NY)

Shortwave Signal Propagation 2017 Eclipse

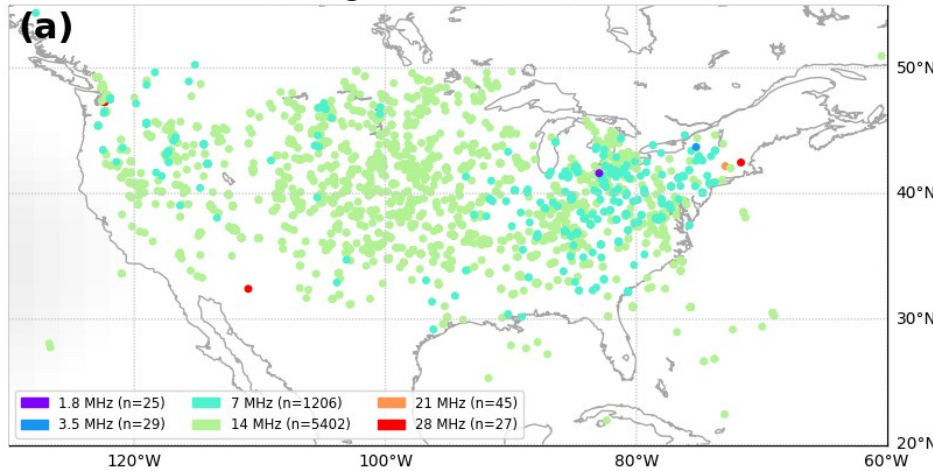


Even shortwave listeners got into the act. Using the S meter on his Panasonic RF-4900 shortwave receiver, 88 year old John S. Erickson of Schenectady, NY (father of Extra class licensee and professional ionospheric researcher Phil Erickson W1PJE) recorded the signal strength he heard from time signals WWV at 10 and 15 MHz every 10 minutes during eclipse passage.

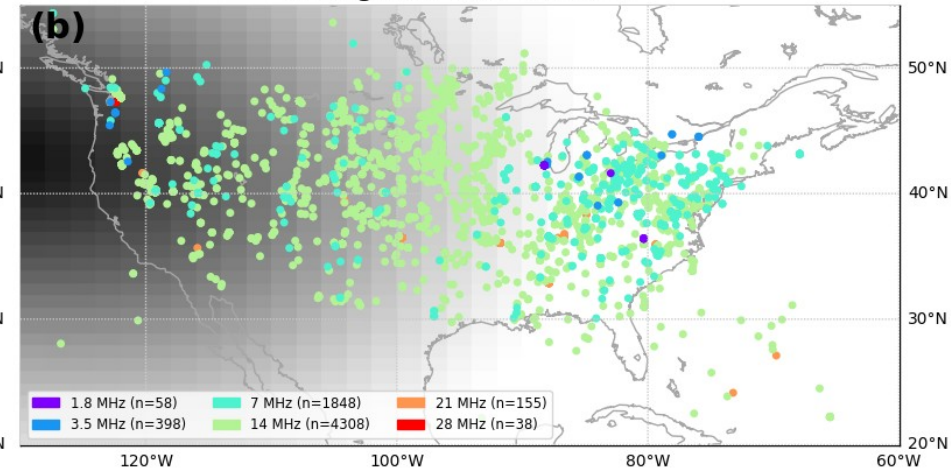
# RBN - SEQP

## RBN Spot Midpoints; 300.0 km Obscuration Altitude

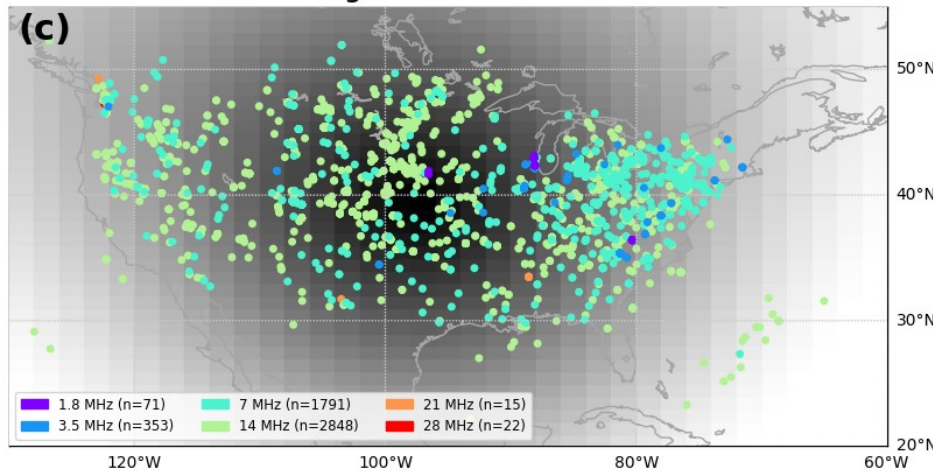
21 Aug 2017 1600-1605 UT



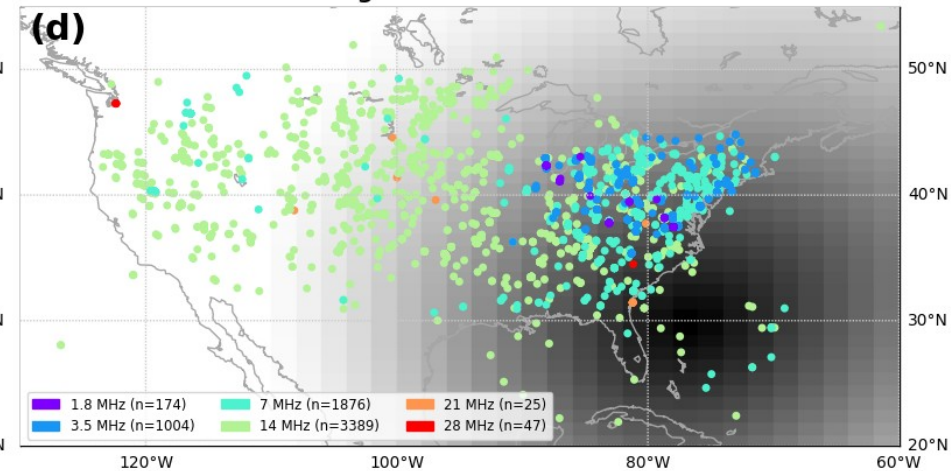
21 Aug 2017 1700-1705 UT



21 Aug 2017 1800-1805 UT

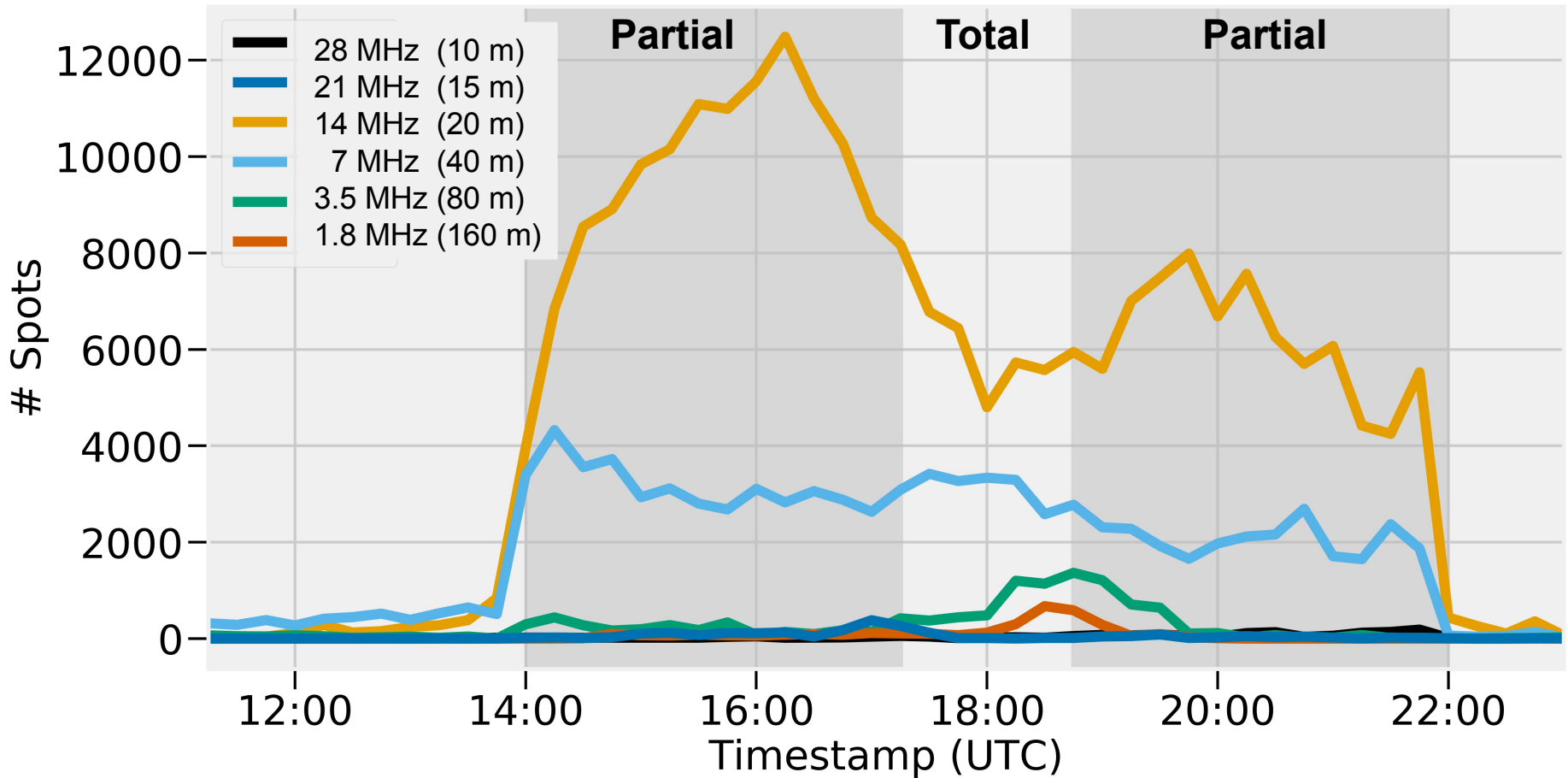


21 Aug 2017 1900-1905 UT



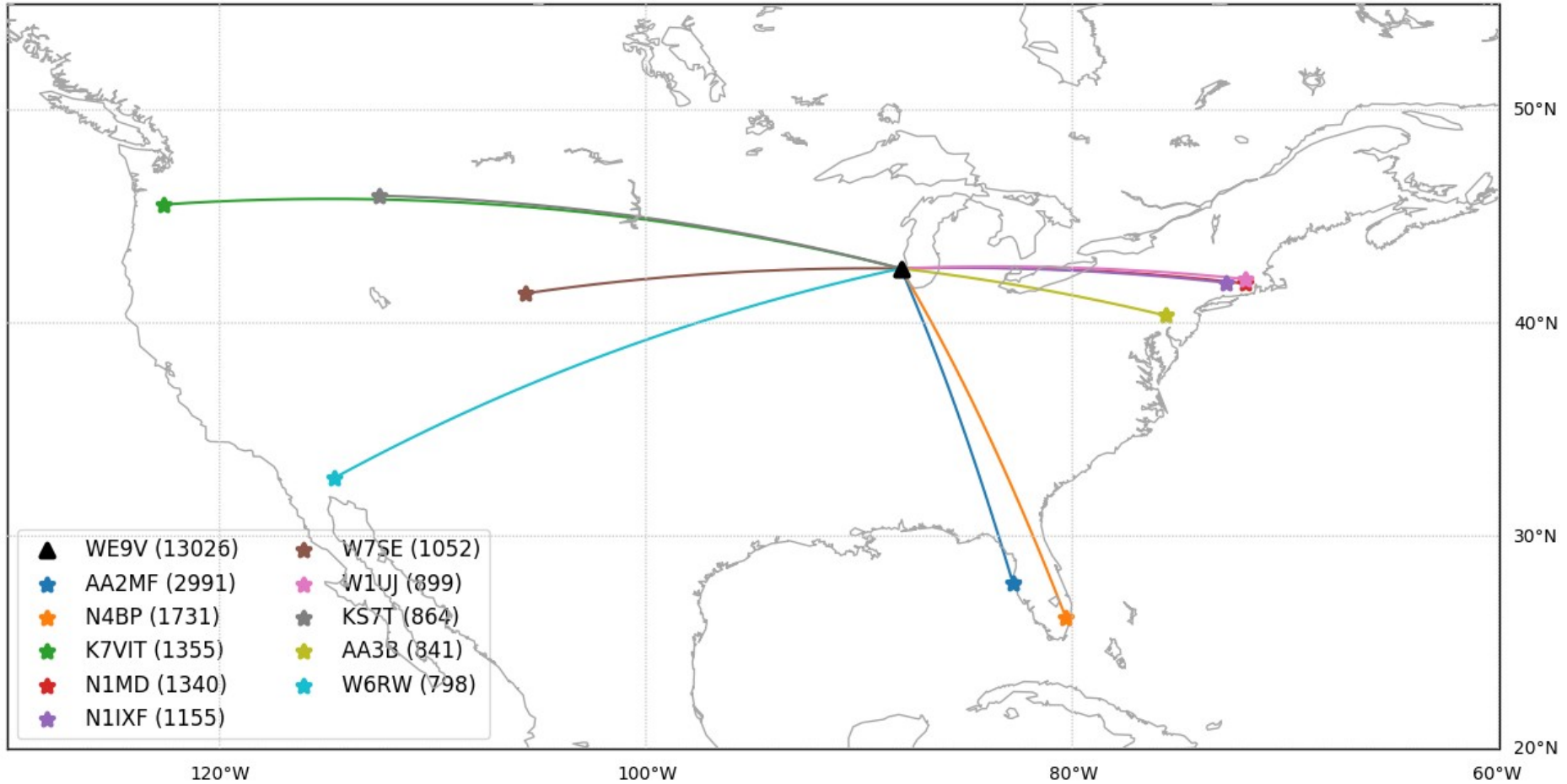
# SEQP RBN Spots

RBN SEQP Spots by Band (Contiguous US TX and RX Only)



# WE9V 14 MHz RBN Rx, Wisconsin

**WE9V RBN Pairs**  
**20 m Eclipse**  
**21 Aug 2017 1400 UT - 21 Aug 2017 2159 UT**





# WE9V 14 MHz RBN Rx, Wisconsin

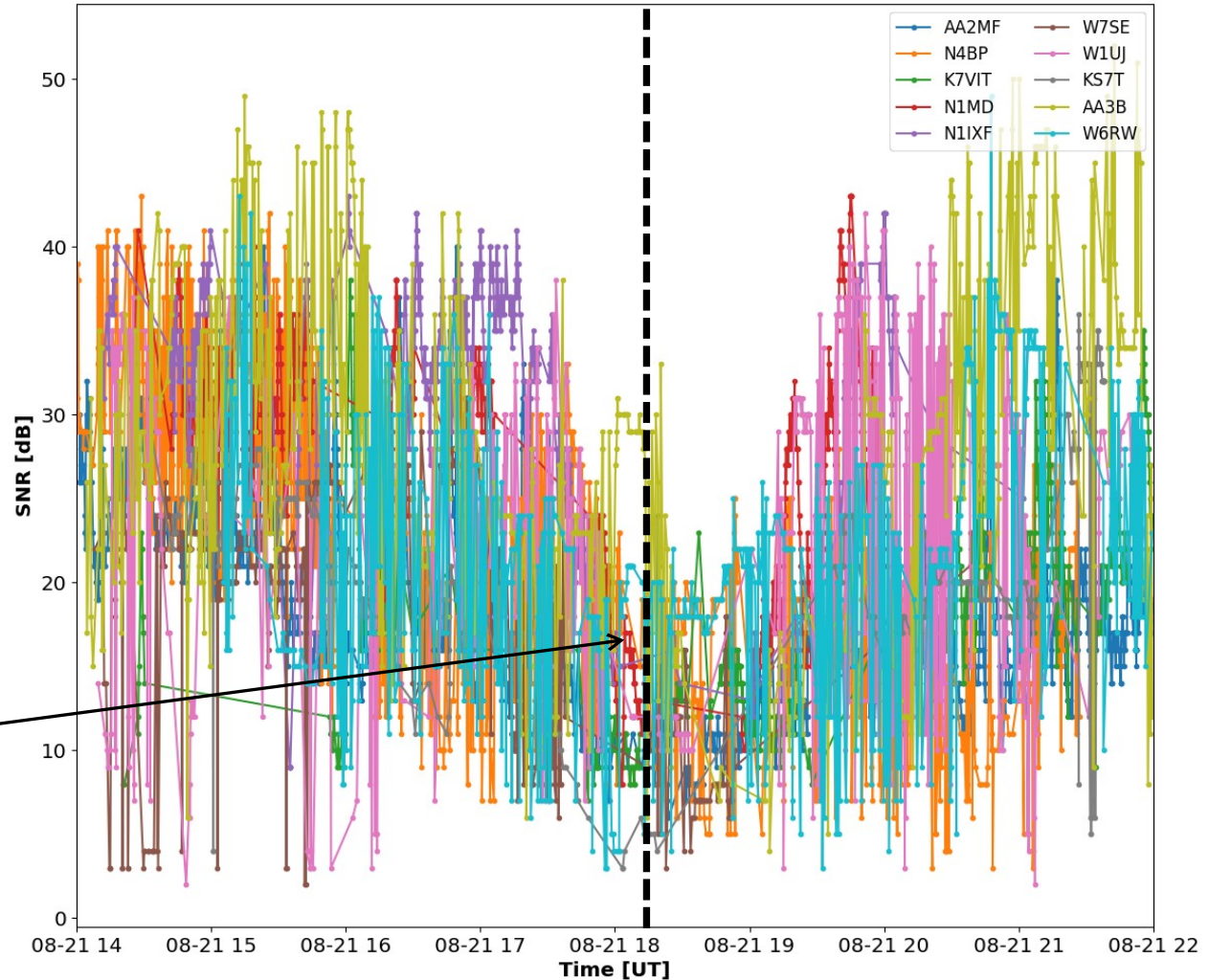
WE9V RBN Pairs  
20 m Eclipse  
21 Aug 2017 1400 UT - 21 Aug 2017 2159 UT

## Ground Eclipse Times

Bristol, WI:

- Start partial: 1653 UT
- Max: 1818 UT
- End partial: 1940 UT

Clear drop in 20 meter propagation during temporary 'nighttime' conditions





# HamSCI Workshop at NJIT

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Friday, Feb. 23 – Saturday, Feb. 24, 2018

New Jersey Institute of Technology

Newark, NJ



We welcome papers and presentations on  
2017 Eclipse Ionospheric Effects using  
Amateur Radio and related data.

*Watch [hamsci.org](http://hamsci.org) and ARRL news for details.*

# HamSCI

The Ham radio Science Citizen Investigation is:



[hamsci.org/dayton2017](http://hamsci.org/dayton2017)

An organization 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 community and the general public.



Founder/Lead HamSCI Organizer:  
**Dr. Nathaniel A. Frissell, W2NAF**  
NJIT Center for Solar-Terrestrial Research

HamSCI  
<http://hamsci.org>



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