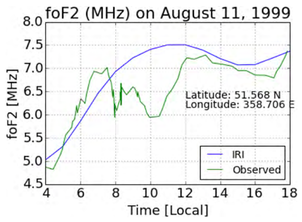
Ionospheric Simulations of the 2017 Solar Eclipse QSO Party

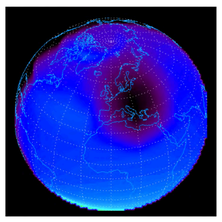
N.A. Frissell[1], J.S. Vega[1], J.D. Katz[1], M.L. Moses[2], G.D. Earle[2], S.W. Gunning[1], A.J. Gerrard[1], E.S. Miller[3], M.L. West[4], F. Ceglia[5], D. Pascoe[5], N. Sinanis[5], P. Smith[5], R. Williams[5], A. Shovkoplyas[6], H.W. Silver[7]

[1]New Jersey Institute of Technology [2]Virginia Tech [3]Johns Hopkins University Applied Physics Laboratory [4]Montclair State University [5]Reverse Beacon Network [6]Afreet Software, Inc. [7]American Radio Relay League

Introduction

A total solar eclipse will traverse the continental United States on 21 August 2017. In addition to their stunning visual effects, solar eclipses are also known to impact the ionosphere [e.g., *Benyon and Brown*, 1956; *Evans*, 1965; *Krankowski et al.*, 2008]. Although the ionospheric effects of eclipses have been studied for more than 60 years, the spatial and temporal extent of these effects are still not well understood.





(Left) Ionosonde measurements show a decrease in the foF2 parameter during the 1999 U.K. eclipse compared to expected values from a non-eclipsed Intl. Reference Ionosphere (IRI). Adapted from Afraimovich et al., 2002.

(Right) Model electron density at ~280 km alt. during 1999 Eclipse [Bamford, 2000].

Data and Methodology

Amateur Radio Observations

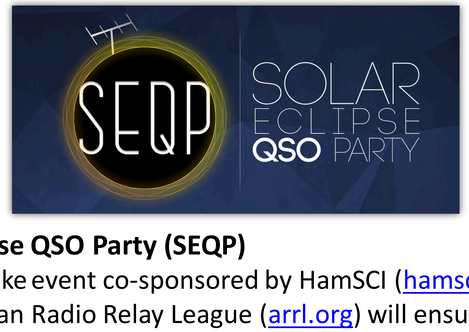
This poster focuses on a Citizen Science approach using amateur (ham) radio to generate data that will complement traditional measurement techniques.

- Amateur radio operators use transionospheric links on HF (1.8 – 30 MHz) radio frequencies.
- Voluntarily operated monitoring networks such as the Reverse Beacon Network (RBN), PSKReporter, and WSPRNet archive observations of radio transmissions.
- The data from these archives can be used to study space weather events [*Frissell et al.*, 2014].

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

Common frequencies used by amateur radio operators.

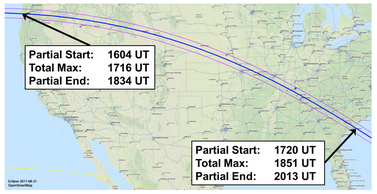
NJIT students operate the K2MFF amateur radio station during a contest. Ham radio stations vary in capability. Transmit powers range from a few mW to 1500 W in the U.S.



Solar Eclipse QSO Party (SEQP)

A contest-like event co-sponsored by HamSCI (hamsci.org) and the American Radio Relay League (arrl.org) will ensure sufficient ham radio data is generated during the eclipse.

- The SEQP takes place 1400 – 2200 UT 21 August 2017.
- Participants earn points by making radio contacts.
- Full rules available at http://hamsc.org/seqp.



Eclipse totality (between the red lines) will traverse from Oregon to South Carolina in 95 minutes. The SEQP will begin about 2 hours before partial eclipse starts in Oregon and end about 2 hours after partial eclipse ends in South Carolina.

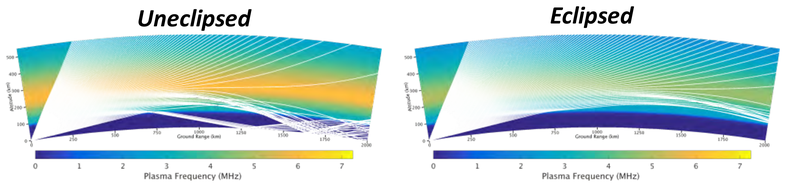
W. Strickling - Eclipse 2017 Android App, Geodata from OpenStreetMap, CC BY-SA 2.5, https://goo.gl/gBufJ9

PHaRLAP HF Raytracing and Eclipse Ionosphere Model

To predict SEQP results and aid in the interpretation of collected data, we ran the PHaRLAP HF Raytracing toolbox [*Cervera and Harris,* 2014] on the NJIT Kong computer cluster.

Simulation parameters:

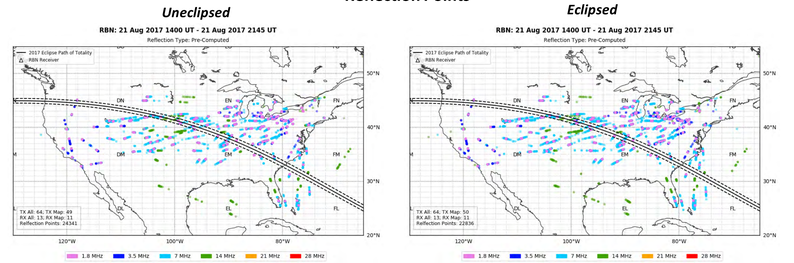
- **TX/RX Pairs:** RBN data from 1–3 Nov 2014 was used to identify transmitters (TX) and receivers (RX) from the 2014 ARRL CW Sweepstakes, an event similar to the SEQP. A total of 1369056 were used.
- **Frequencies:** 1.83, 3.53, 7.03, 14.03, and 21.03 MHz.
- **Times:** 1400 – 2145 UT 21 August 2017 at 15 min cadence
- **Ionospheres:**
  - Unmodified IRI-2016 [*Bilitza*, 2011]
  - IRI-2016 modified with *Moses et al.* [2017] eclipse attenuation function.



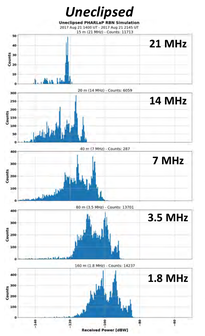
PHaRLAP Raytraces from transmitter Platteville, CO (AA0RS) to Pipersville, PA (WZ7I) at 1815 UT 21 Aug 2017 on 14.030 MHz. (left) Uneclipsed IRI2016 (right) IRI2016 with eclipse attenuation function applied.

Results

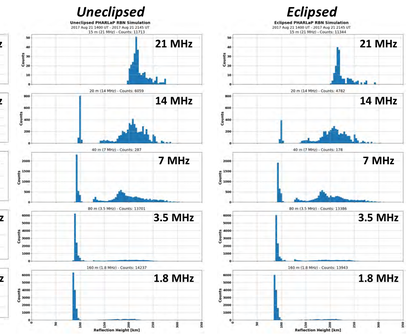
Reflection Points



Received Power



Reflection Height



Summary & Discussion

- The Solar Eclipse QSO Party (SEQP), a large-scale ham radio event, will take place during the 2017 eclipse to generate data for studying the ionospheric response to the eclipse.
- HF raytracing has been implemented for the purpose of interpreting future SEQP observations.
- We do not currently see a substantial difference between the eclipsed and uneclipsed SEQP simulation results.
- Further work will be done to see if different analysis or a modified eclipse model must be used to see eclipse effects.

References and Acknowledgments

E.L Afraimovich, 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.

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

Benyon, W. J. G., and G. M. Brown (Eds.) (1956), Solar Eclipses and the Ionosphere, Proceedings of the Symposium held under the auspices of the International Council of Scientific Unions Mixed Commission on the Ionosphere in London, August 1955, Permagon Press.

Bilitza, D., McKinnell, LA., Reinisch, B. et al. J Geod (2011) 85: 909. doi:10.1007/s00190-010-0427-x

Cervera, M. A., and T. J. Harris (2014), Modeling ionospheric disturbance features in quasi-vertically incident ionograms using 3-D magnetoionic ray tracing and atmospheric gravity waves, J. Geophys. Res. Space Physics, 119, 431–440, doi:10.1002/2013JA019247.

Evans, J. V. (1965), An F region eclipse, J. Geophys. Res., 70(1), 131–142, doi:10.1029/JZ070i001p00131.

Frissell, N. A., E. S. Miller, S. R. Kaeppler, F. Ceglia, D. Pascoe, N. Sinanis, P. Smith, R. Williams, and A. Shovkoplyas (2014), Ionospheric Sounding Using Real-Time Amateur Radio Reporting Networks, *Space Weather*, 12, 651–656, doi:10.1002/2014SW001132.

Krankowski, A., I. I. Shagimuratov, L. W. Baran, and G. A. Yakimova (2008), The effect of total solar eclipse of October 3, 2005, on the total electron content over EuropeKran, Adv. in Space Res., 41 (4), 628–638, doi:10.1016/j.asr.2007.11.002.

Moses, M.L., S. Burujupalli, K. Brosie, S. Dixit, G.D. Earle, L. Kordella, N.A. Frissell, C. Chitale (2017), Analysis of the August 2017 Eclipse's Effect on Radio Wave Propagation Employing a Raytrace Algorithm, NSF CEDAR Workshop, Keystone, CO.

The results published in this paper were obtained using the HF propagation toolbox, PHaRLAP, created by Dr. Manuel Cervera, Defence Science and Technology Group, Australia (manuel.cervera@dsto.defence.gov.au). This toolbox is available by request from its author.

The work presented here was supported by the National Science Foundation Office of Polar Programs. We gratefully acknowledge NSF grants PLR-1247975 and PLR-1443507 which supports work at SPA and MCM, and partially supports AGO field operations on the Antarctic plateau.

Banner photo by Ann Marie Rogalcheck-Frissell.

nathaniel.a.frissell@njit.edu

CEDAR • 20 June 2017 • ITIT-10