August 21, 2017 provided a unique opportunity to investigate the effects of the total solar eclipse on high frequency (HF) radio propagation and ionospheric variability at Marshall Space Flight Center’s partnership with the US Space and Rocket Center (USSRC) and Austin Peay State University (APSU), we engaged citizen scientists and students in an investigation of the effects of an eclipse on the mid-latitude ionosphere. Activities included fieldwork and station-based data collection of HF amateur radio frequency bands and VLF radio waves before, during, and after the eclipse to build a continuous record of changing propagation conditions as the moon’s shadow moved across the United States. Post-eclipse radio propagation analysis provided insights into ionospheric variability due to the eclipse.

**OBJECTIVES**

- Observe the propagation of HF radio signals that may be influenced by changes in the ionosphere local to the eclipse shadow.
- Engage student and citizen scientists to participate in, and contribute to, a solar eclipse radio science investigation.
- "Continuation and extension of the amateur’s proven ability to contribute to the advancement of the radio art (see F.C. 97, 97:1-1b)."
- Investigate the way eclipse radio propagation conditions evolve in a manner similar to day/night transition scenarios that occur at the dawn and dusk terminons (Smith and Silver, 2016).
- Explore changes in radio propagation in terms of evolving ionospheric conditions as the eclipse shadow moves across the U.S.
- Have Fun!

**HYPOTHESIS**

It has long been known that the Earth’s ionosphere responds to changes in solar illumination during a solar eclipse (e.g., Chapman, 1931; Hulbert, 1941; Mitra, 1952; Davies, 1990). Changes to the ionosphere during an eclipse will influence the propagation of radio waves traversing the ionosphere, and could be explained by observing the behavior of radio propagation.

**BACKGROUND**

Radio propagation at low HF frequencies (30 meters, 60 MHz, 3.5-4.0 MHz) and 40 meters (40M, 7.0 – 7.3 MHz) are typically good during the night, but during the day, the D-Region ionospheric density increases due to ionization, and the lower frequency waves are attenuated via wave absorption. In the ionospheric D Region, radio wave absorption per unit path length is roughly proportional to \( n^2 \), where \( n \) is electron density, \( \lambda \) is collision frequency, and \( \phi \) is radio wave angular frequency. As solar illumination and ionization decrease in the shadow of the eclipse, electrons recombine with ions at a faster rate than they are produced. The result is a decrease in \( n \), and the product \( n^2 \) during eclipse resulting in less absorption (Davies, 1990). Monitoring lower band HF propagation will help understand and interpret eclipse effects.

**Weak Signal Propagation Reporter (WSPR)**

WSPR is a global amateur radio propagation reporting system, similar to RTTY but with advantages (e.g., very low power, low error rates). Key to the success of the RBN and WSPR is the participation of hundreds of Amateur Radio volunteers who maintain these global propagation reporters.

**Reverse Beacon Network (RBN)**

RBN stations collect reports of received signals and send them back to central databases where they are archived and displayed in near real-time on the RBN website (reversebeacon.net). This website provides key information needed to characterize radio propagation conditions. RBN receiver "blimzer" servers generate reports ("reports") by decoding continuous wave (CW) signals (e.g. Morse code), telegraphs and more modern digital formats.

**Propagating path at lower (right), higher (left) frequencies and fade off angles.**

Left, normal day 80M and 40M signal paths.
Right, signal path during eclipse.

**REVIEWS AND DISCUSSIONS**

- Observations of low-level solar activity on August 20, 2017, and the propagation of CW signals above 10 MHz on 80 meters.
- The effect of the solar eclipse of August 21, 2017, on HF radio propagation.
- Changes in radio propagation during the eclipse.
- The impact of solar eclipses on radio propagation.
- Observations of the propagation of HF radio waves during the total solar eclipse of August 21, 2017.

**FUTURE WORK**

- The effects of the solar eclipse on radio propagation.
- The impact of solar eclipses on radio communications.
- Observations of the propagation of HF radio waves during the total solar eclipse of August 21, 2017.

**CONCLUSIONS**

Our eclipse radio science campaign during the total 2017 solar eclipse demonstrated that meaningful science can be done on a shoestring budget, while engaging citizen scientists. We look forward to exciting results from further analyses, and results from the broader HamSCI community. However, data quality can be impacted by the social nature of such crowd-sourcing observations due to uncertainties in the reliability of user-provided information (e.g., location, timing, and consistency of transmitter effective radiative power (ERP)).

Next Steps:

1. Plan to install the RBN skimmer server at NASA Marshall Space Flight Center (MSFC) to fill a sorely needed gap in RBN observation coverage in the southeast U.S. to use as a teaching resource, and to enable new MSFC ionospheric and radio propagation research and public outreach.
2. The experience and knowledge gained, and mistakes made, will better prepare us for future eclipse radio science campaigns. On to Chile in 2019!