INTRODUCTION

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 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 marched 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 ionospheric local to the eclipse shadow.
• Engage student and citizen volunteers 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” (CC 97. 697.1.b)
• Investigate the way eclipse radio propagation conditions evolve in a manner similar to day/night transition scenarios that occur at the dawn and dusk terminators (Smith and Silver, 2016).
• Explore changes in radio propagation in terms of evolving ionospheric conditions as the eclipse shadow marches 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 in the ionosphere during an eclipse would influence the propagation of radio waves traversing the ionosphere, and could be explained by observing the behavior of radio propagation.

The most dramatic changes in radio signal strength during the eclipse should occur in the ionospheric D Region (e.g., Nichols, 2015).

BACKGROUND

Radio propagation at low HF frequencies (30 meters [30M], 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 ionisation, and the lower frequency waves are attenuated via radio wave absorption. In the ionospheric D region, radio wave absorption per unit path length is roughly proportional to n_e2 (i.e., ne2), where ne is electron density, c is collision frequency, and u is radio wave angular frequency.

As solar illumination and ionisation 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 ne, and the product ne2 during eclipse resulting in less absorption (Davies, 1990). Monitoring lower band HF propagation can help intercept and understand eclipse effects.

Weak Signal Propagation Reporter Network (WSPR)

Network (WSPRNet) is a global amateur radio propagation reporting system, similar to RBN 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.

Weak Signal Propagation Reporter Network Propagation Post – 80MHz band (3.5 MHz)

NNSA WSPR Transmitter

NASA Marshall Space Flight Center

Huntsville, AL (44.649, 86.486)

Figure 1: WSPR propagation post-80 MHz band showing weak signal propagation reporter network locations.

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Figure 2: WSPR propagation post-80 MHz band showing weak signal propagation reporter network locations.

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Reverse Beacon Network (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). The RBN provides key information needed to characterize radio propagation conditions. RBN receiver “blitzers” generate reports (“spots”) by decoding continuous wave (CW) e.g. Morse code, telegraphy and more modern digital formats.

Reverse Beacon Network Skimmer

Data flow at the WLC7 RBN Skimmer

KIDDR RBN Transmitter

Huntsville, AL (37.044, 87.306) on eclipse centerline, 30 watts heating “L” antenna (gain pattern from WSPR simulations, http://www.hdsdr.de).

Preliminary Results

Preliminary results from analysis of WLC7 RBN data collected on eclipse day indicate an increase in propagation distance on the 40M band during the eclipse. On the 80M band, WSPR receivers from hundreds of kilometers away recorded strong WSPR transmitters, which was not the case on the day after the eclipse. These results point to a decrease in absorption in the D region during the eclipse, which suggests that ionospheric conditions were improving with time.

Three modes that enable propagation of radio waves between two nearby stations include Direct Wave (Line of sight), Groundwave (follows the Earth’s surface), and Near Vertical Incidence Sky Wave (NVIS) via ionospheric refraction. Of the three, WLC7/KIDDR operating band of choice, 40M, WSPR was the most likely mode because distance and terrain put the stations beyond the line of sight, and ground waves are rapidly attenuated. The UMass-LOI GOST database (Reinisch and Galin, 2011), included 6 Digiscope ionospheric scounder stations operating in the main U.S. at 18:00 UT on August 21 near peak eclipse at our field sites. Measured peak plasma frequencies in the F2 layer, foF2, were near 4.0 c/Hz. 0.5 MHz, with the height of F2 layer peak, hmF2, ranging 156-194 km. NVIS propagation between WLC7 and KIDDR (53 km separation) was likely because the high-angle sky wave would have punched through the ionosphere rather than returning to the surface.

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, time, and consistency of transmitter effective radiative power (ERP)).

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