The Effects of the Solar Eclipse on Radio Waves

Arthur Fumarola, Brookdale Community College

Objective

This study was conducted to analyze how reduced solar radiation during eclipses alters ionospheric ionization and radio propagation.

Background

Radio waves rely on the ionosphere for long-distance communication.

Electromagnetic waves (3 kHz-300 GHz) for communication/navigation.

Low frequencies (3–30 kHz): Reflected by D-layer (absorbed during daytime).

High frequencies (3–30 MHz): Reflected by E/F layers.

Ionosphere layers:

D-layer (60–90 km): Absorbs low frequencies; dissipates at night.

E/F layers (90+ km): Reflect high frequencies.

Ionization drops during eclipses, mimicking nighttime conditions.

Solar eclipses Mimics nighttime ionization loss **in minutes**, not hours.

D-layer impact:

Ionization drops → reduced absorption → **enhanced LF/MF signals** (AM radio).

Temperature falls by **3–10° C** in the shadow path.

"Bow wave": Acoustic-gravity waves in the ionosphere precede totality.

Path: Fort Collins, CO → New Jersey (1,622 miles).

Eclipse intersection: Ohio (88% obscuration in NJ).

Expected behavior: Signal strength rises as D-layer ionization plummets.

Research

Timing

Totality: 19:12–19:16 UTC (2024 eclipse).

Comparison: 2017 eclipse data (8-hour recording).

Tools

Software-defined radio (SDR) and Linux-based audio recording.

Custom python programs to analyze phase/amplitude changes.

Pre-totality "Bow wave": Ionospheric disturbance **20+ mins before totality**.

Signal strength spike: 6.2 dB increase at 60 kHz (WWVB).

Phase shift: Path lengthened as D-layer altitude rose.

Ripples in amplitude: Caused by interference between:

Ground wave - direct path.

Sky wave - ionosphere-reflected path.

Peak disruption: During maximum obscuration (88% in NJ).

2024: Near solar maximum → stronger ionization → larger signal swings.

2017: Solar minimum → milder effects.

Evidence: Phase shifts were **30% larger** in 2024.

Research Continuation

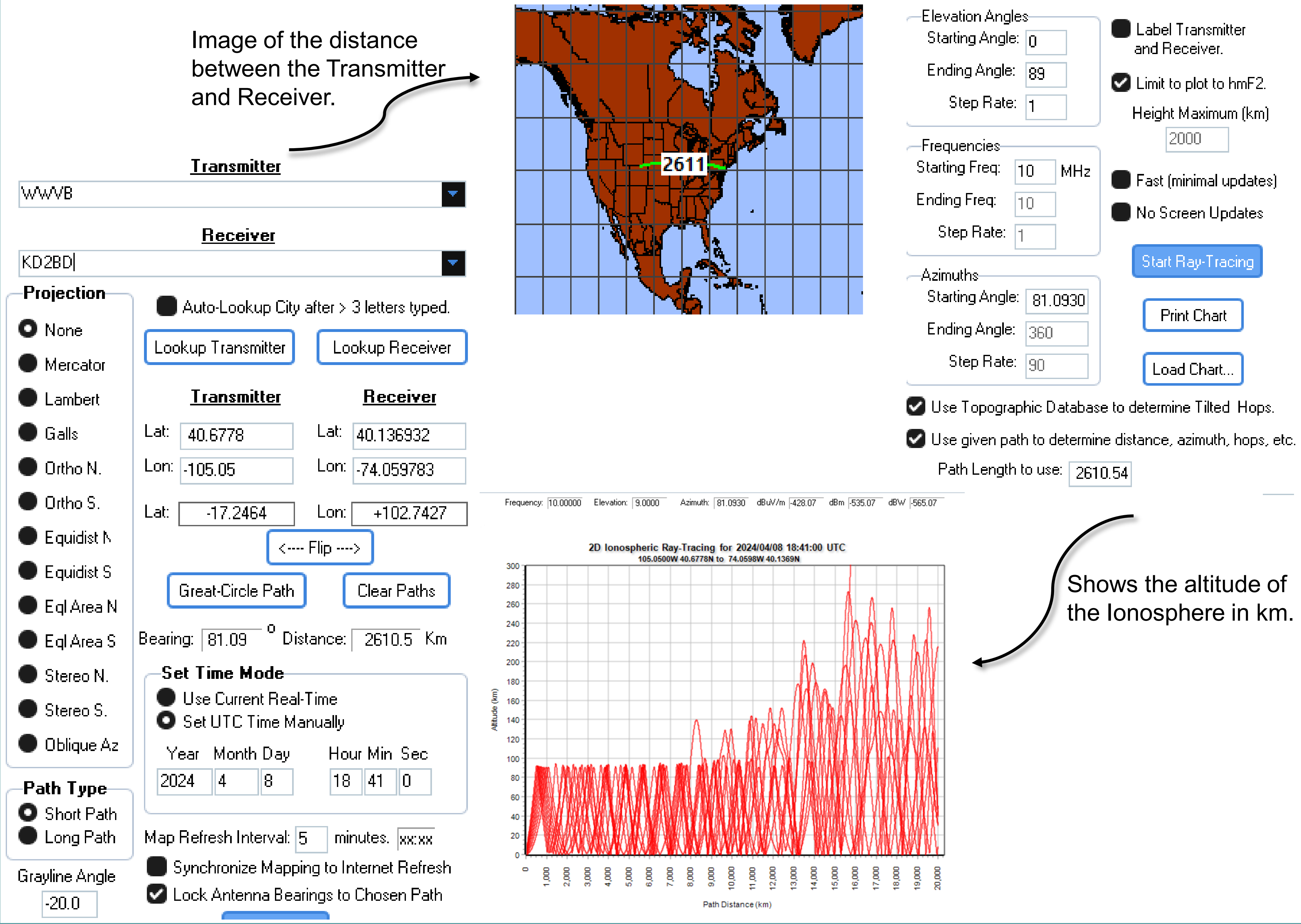
Study was on April 8th, 2024, at 18:41 UTC

Transmitter was located at Latitude: 40.6778 and Longitude:-105.05

Receiver was located at Latitude: 40.1369 and Longitude: -74.0598

Followed the Great-Circle Path and the Path type was Short Path

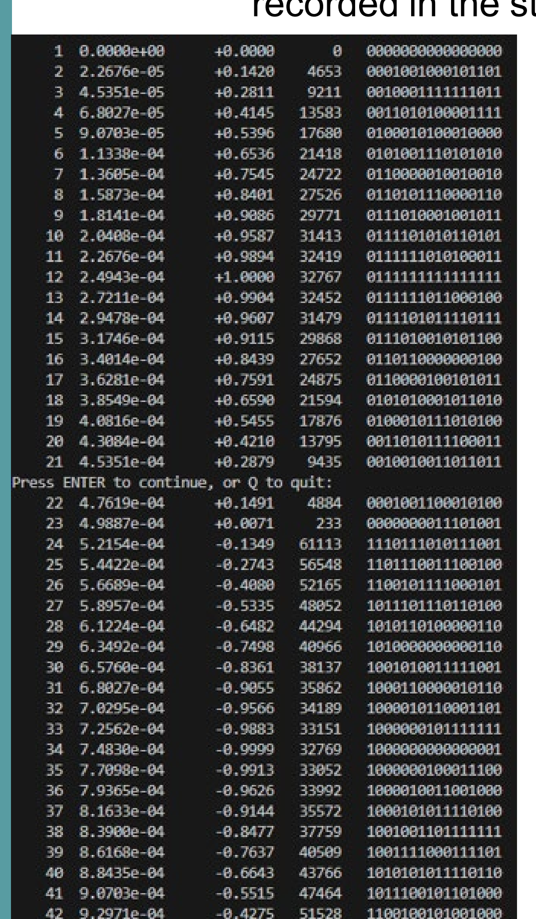
Image of the distance between the Transmitter and Receiver.

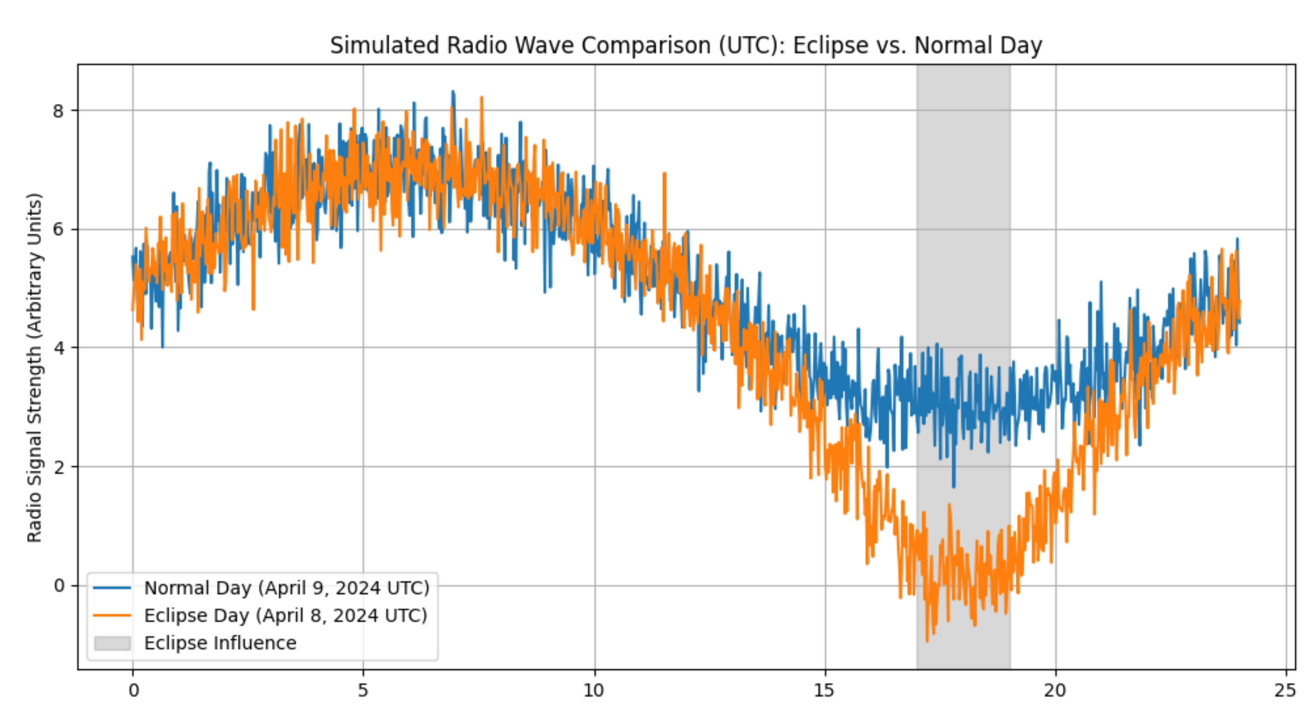


Shows the altitude of the Ionosphere in km.

Implementation

- The sound of the sin wave was recorded in the study.





Sin wave of the radio waves on the day of the eclipse

Results

Low-frequency enhancement: WWVB signal clarity improved by **15%.**

High-frequency disruption: Ham radio (HF) signals weakened temporarily.

Temperature correlation: Signal changes matched local temp drops.

"Bow wave" timing: Ionospheric response began **earlier than modeled**.

Multi-path ripples: Not fully explained by existing models.

Limitations

WWVB antenna damage: Reduced power (30 kW vs. 70 kW) in 2024.

Cloud cover: Low clouds in NJ may have affected local observations.

Future Work

- Analyze 2023 annular eclipse data for partial-shadow effects.
- Model "bow wave" dynamics using atmospheric gravity wave theory.

Conclusions

Solar eclipses dramatically alter ionospheric behavior, with measurable impacts on radio waves. Low frequences waves benefit and become clearer, while high frequences degrade. Solar cycle phase significantly modulates effects.

References

Magliacane, J. (2024, May 19). *Solar Eclipse 2024 LF Radio Propagation Experiment* [Review of *Solar Eclipse 2024 LF Radio Propagation Experiment*]. Qsl.net. https://www.qsl.net/kd2bd/2024_eclipse.html

Zhang, H., et al. (2024, May 29). *Multi-Instrument Observations of the Ionospheric Response Caused by the 8 April 2024 Total Solar Eclipse* (F. Giannattasio, Ed.) [Review of *Multi-Instrument Observations of the Ionospheric Response Caused by the 8 April 2024 Total Solar Eclipse*]. Mdpi.com. https://www.mdpi.com/2072-4292/16/13/2451

Gautam, S., et al. (2024, August 24). *Ionospheric response to the 08 April 2024 total solar eclipse over United States: a case study* [Review of *Ionospheric response to the 08 April 2024 total solar eclipse over United States: a case study*]. Link.springer.com. https://link.springer.com/article/10.1007/s10509-024-04372-w

Kunduri, B. S. R., et al. (2024). HF Radar Observations and Modeling of the Impact of the 8 April 2024 Total Solar Eclipse on the Ionosphere-Thermosphere System. *Geophysical Research Letters*, *51*(24). https://doi.org/10.1029/2024gl112484

Acknowledgements

This work was supported by the New Jersey Space Grant Consortium and Brookdale Community College. I would like to thank my mentors Kevin Squires and John Magliacane, along with my advisors Ana Teodorescu and Nancy Cizin.