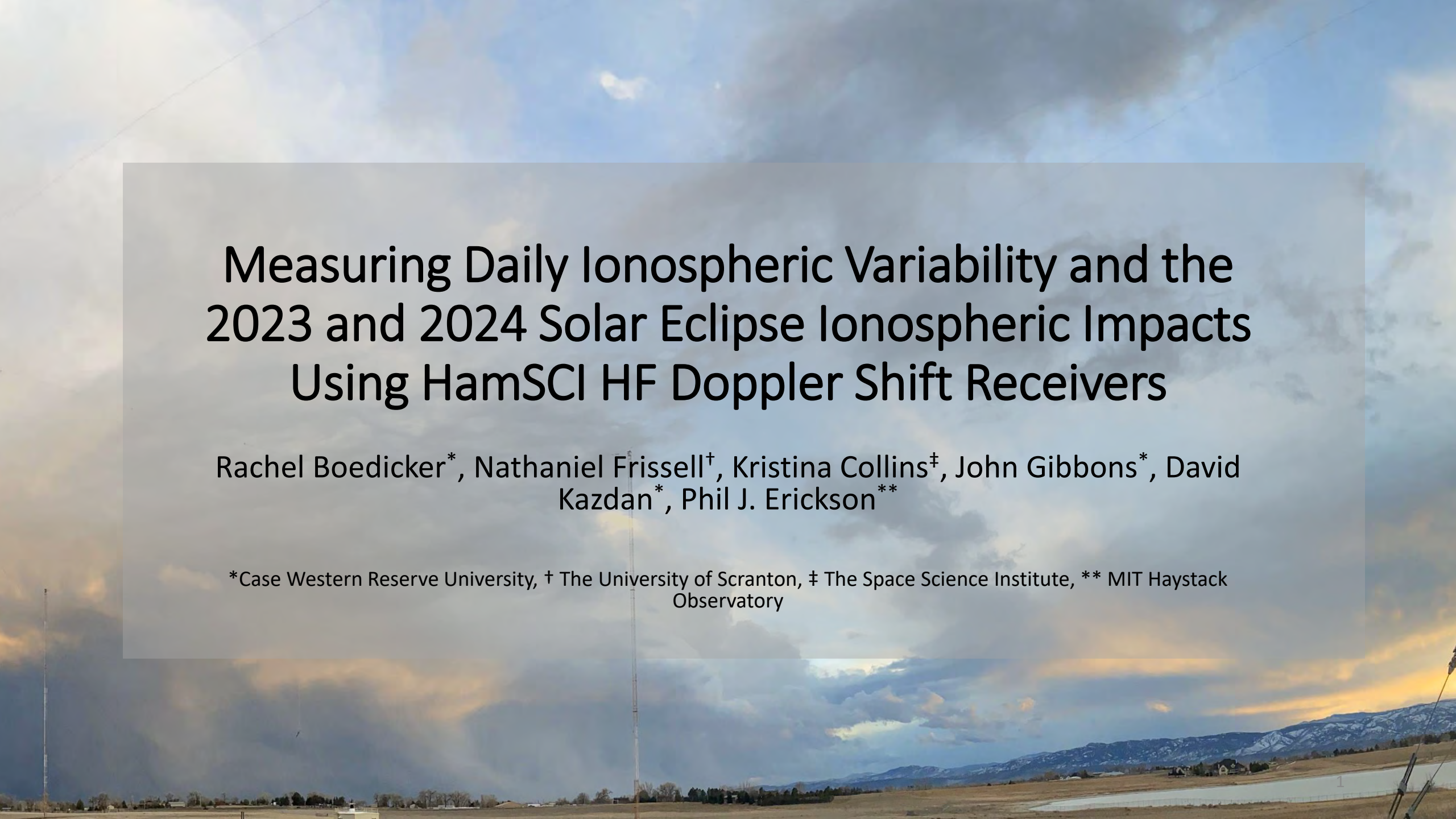


Measuring Daily Ionospheric Variability and the 2023 and 2024 Solar Eclipse Ionospheric Impacts Using HamSCI HF Doppler Shift Receivers

Rachel Boedicker[*], Nathaniel Frissell[†], Kristina Collins[‡], John Gibbons[*], David Kazdan[*], Phil J. Erickson[**]

*Case Western Reserve University, † The University of Scranton, ‡ The Space Science Institute, ** MIT Haystack Observatory

OVERVIEW

1. Introduction
2. Methodology
3. Scientific Questions
4. Project Timeline

Introduction

- A brief note on the ionosphere
- The merit of Solar Eclipses

Ionospheric Layers

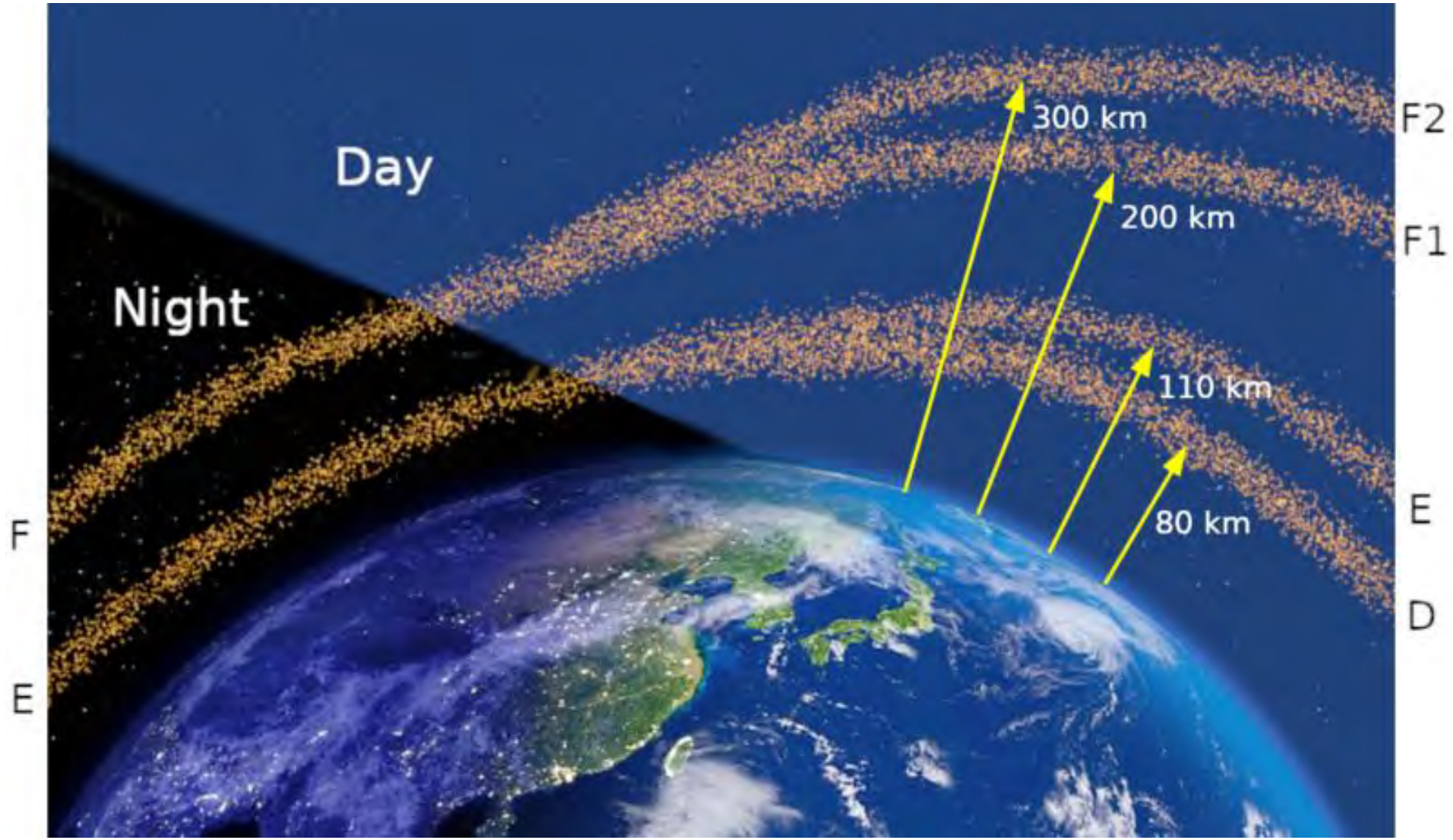


Figure by Carlos Molina

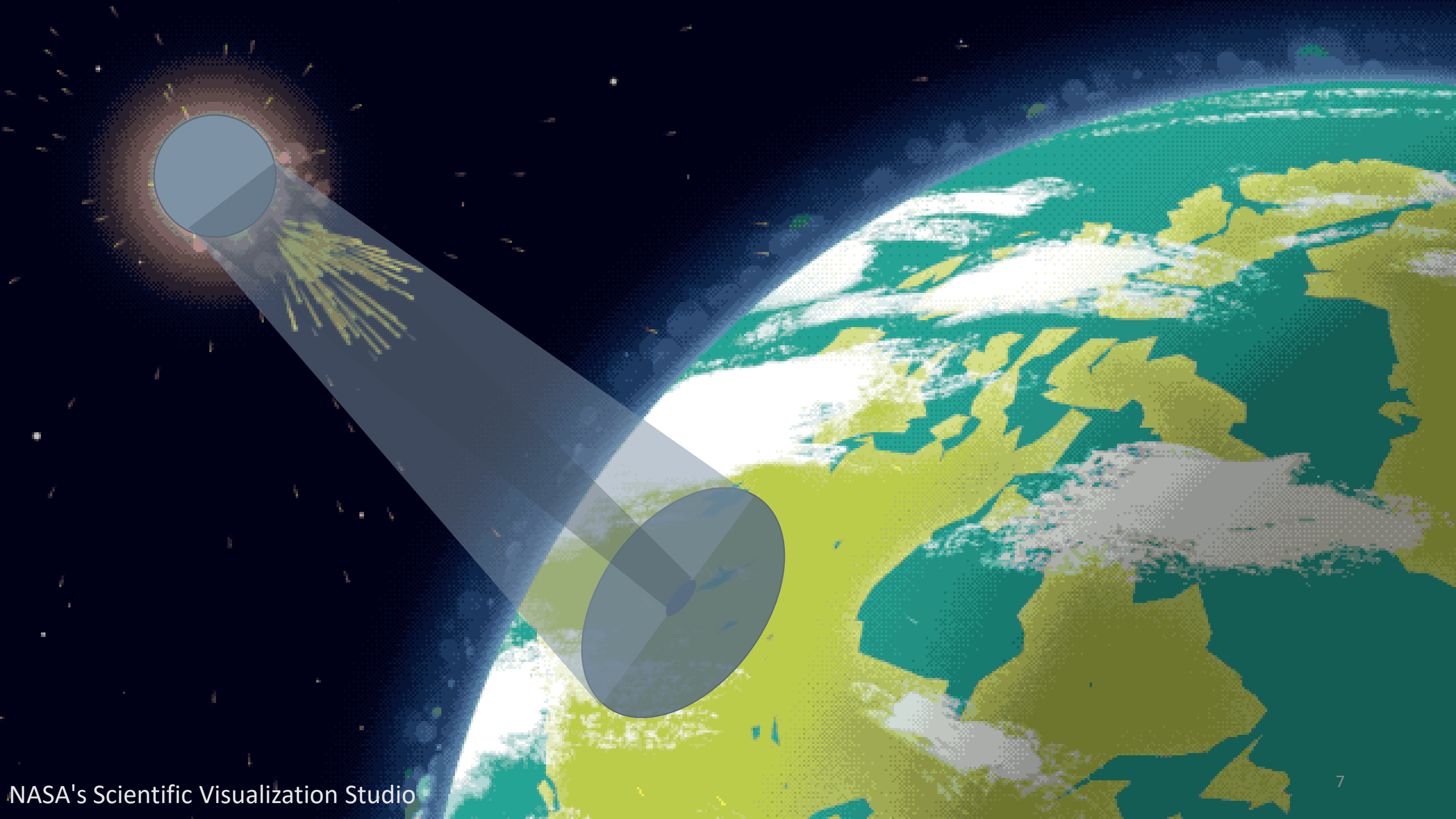
Sources of Ionospheric Variability

- Day/Night (Diel) Shift
- Solar Flares
- Auroral Substorms
- Geomagnetic Storms
- Traveling Ionospheric Disturbances (TIDs) from atmospheric gravity waves (AGWs)
- Solar Eclipses

Solar Eclipse

- Predictable time, path, and solar energy
- Will still vary with season, maximum obscuration (annular, partial, or total), location, direction, and atmospheric state

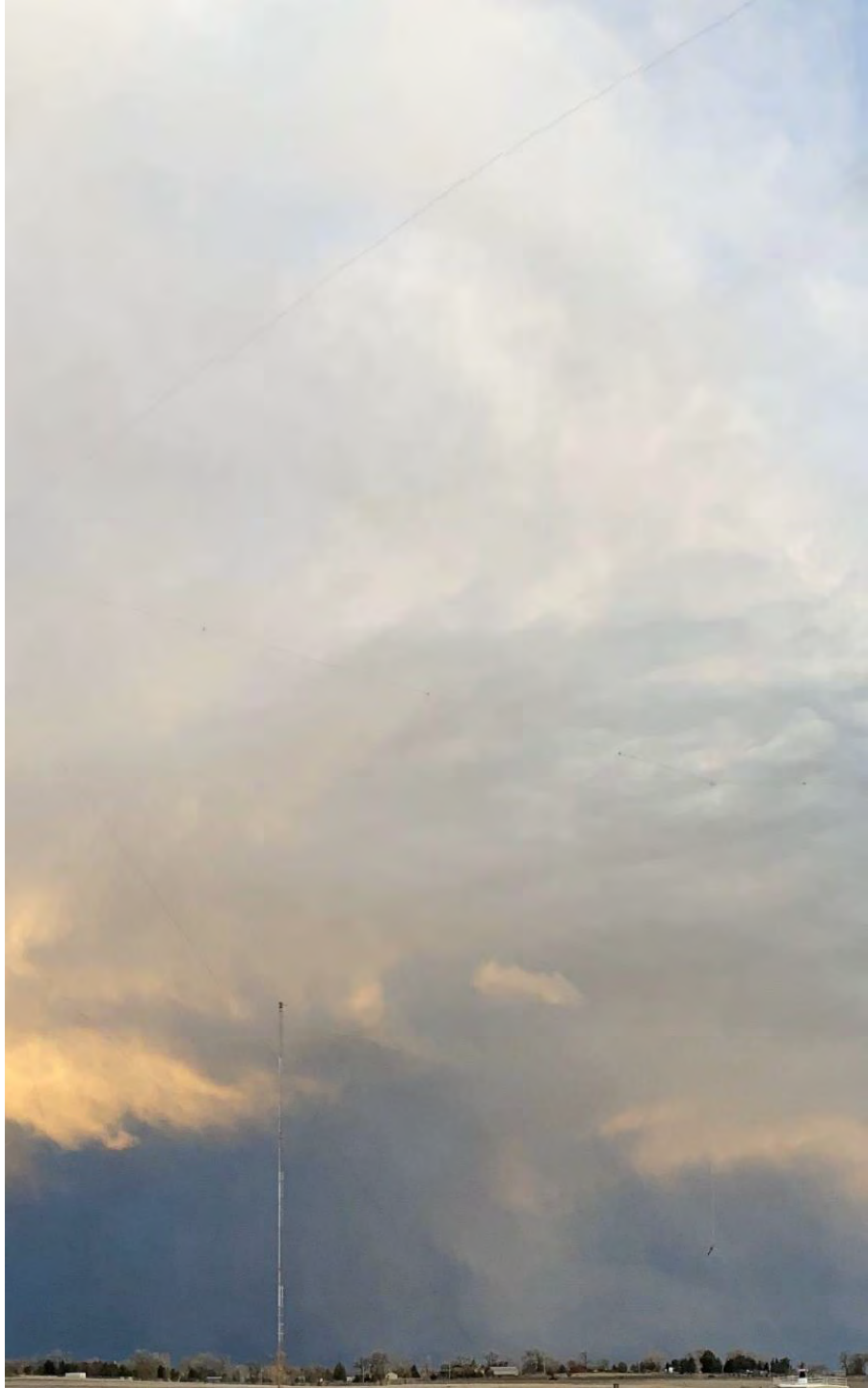
Image by J. Sackerman, KC2ZFK



NASA's Scientific Visualization Studio

Methodology

- Measuring the ionosphere
- Grape PSWS Receiver Network



Measuring Ionospheric Disturbances

Day/Night variation, solar flares, and geomagnetic storms all cause changes in the ionosphere and WWV signal propagation. But one particular event causes a specific, predictable change in solar radiation: a solar eclipse.

How can we go about figuring out

- How will the eclipse affect HF communications?
- How large is the disturbance?
- How similar are the effects of the eclipse to behavior during dawn and dusk?
- How long will the effects last?

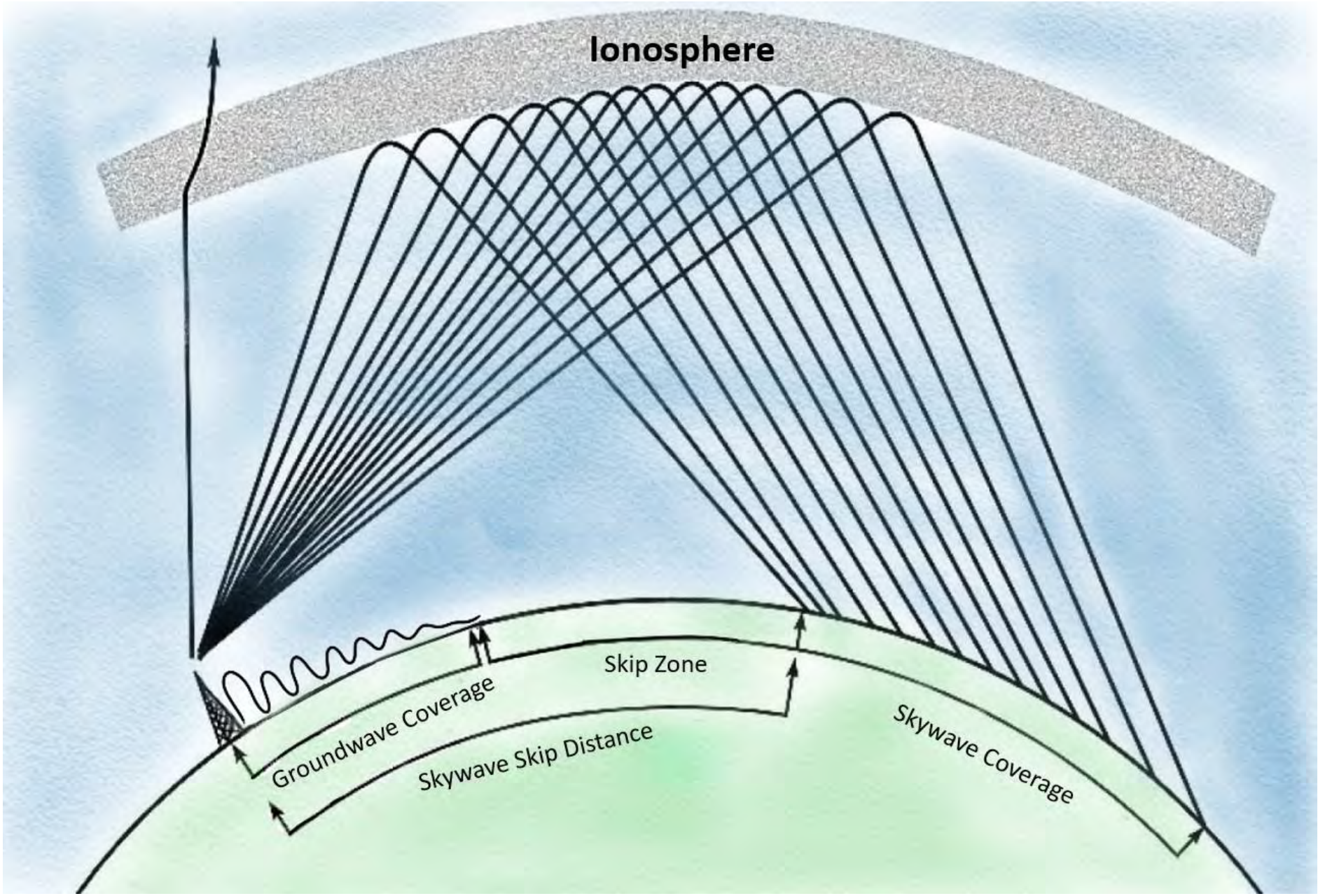
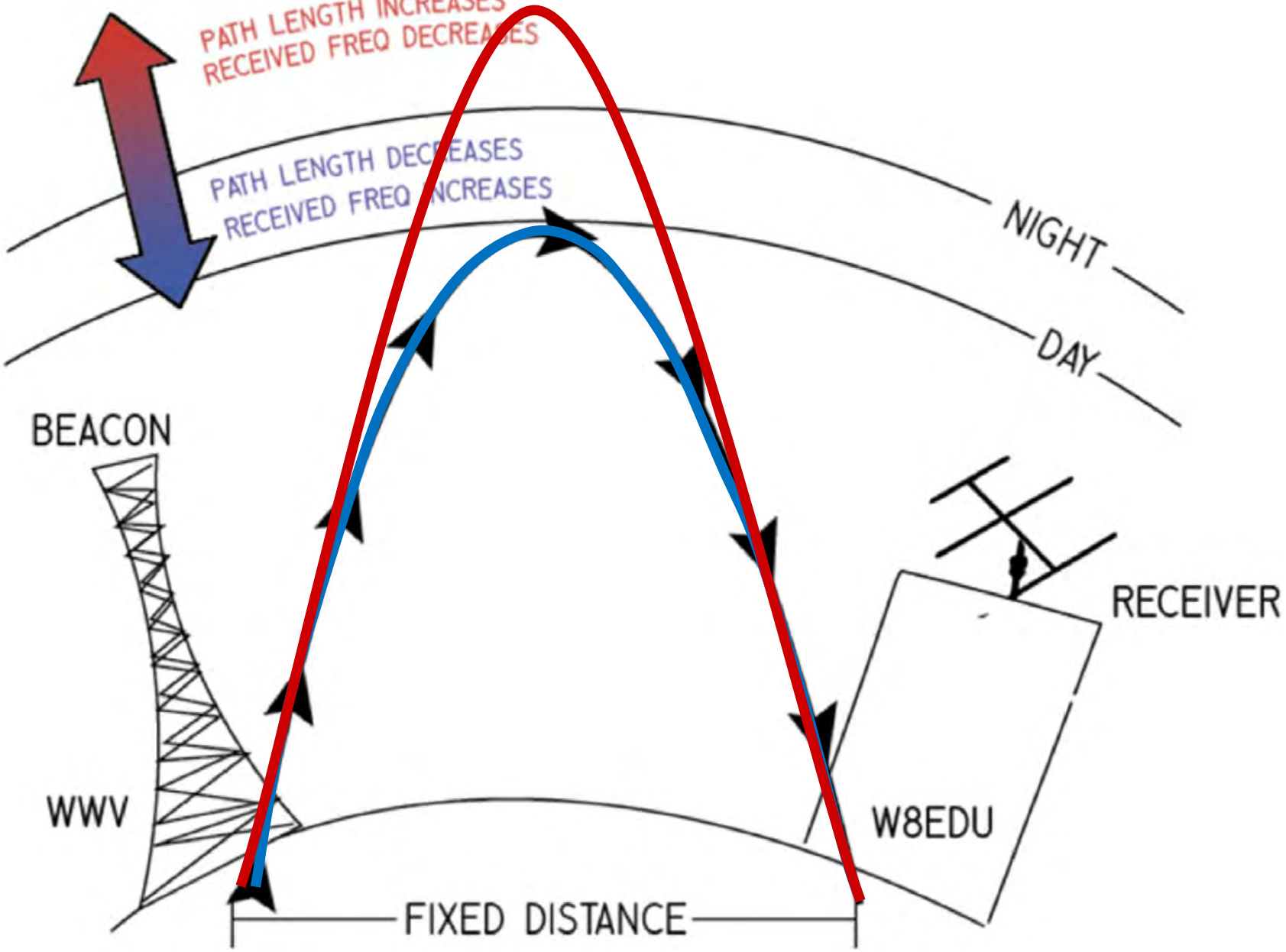


Image by Juliana Lombardi

Doppler Shift

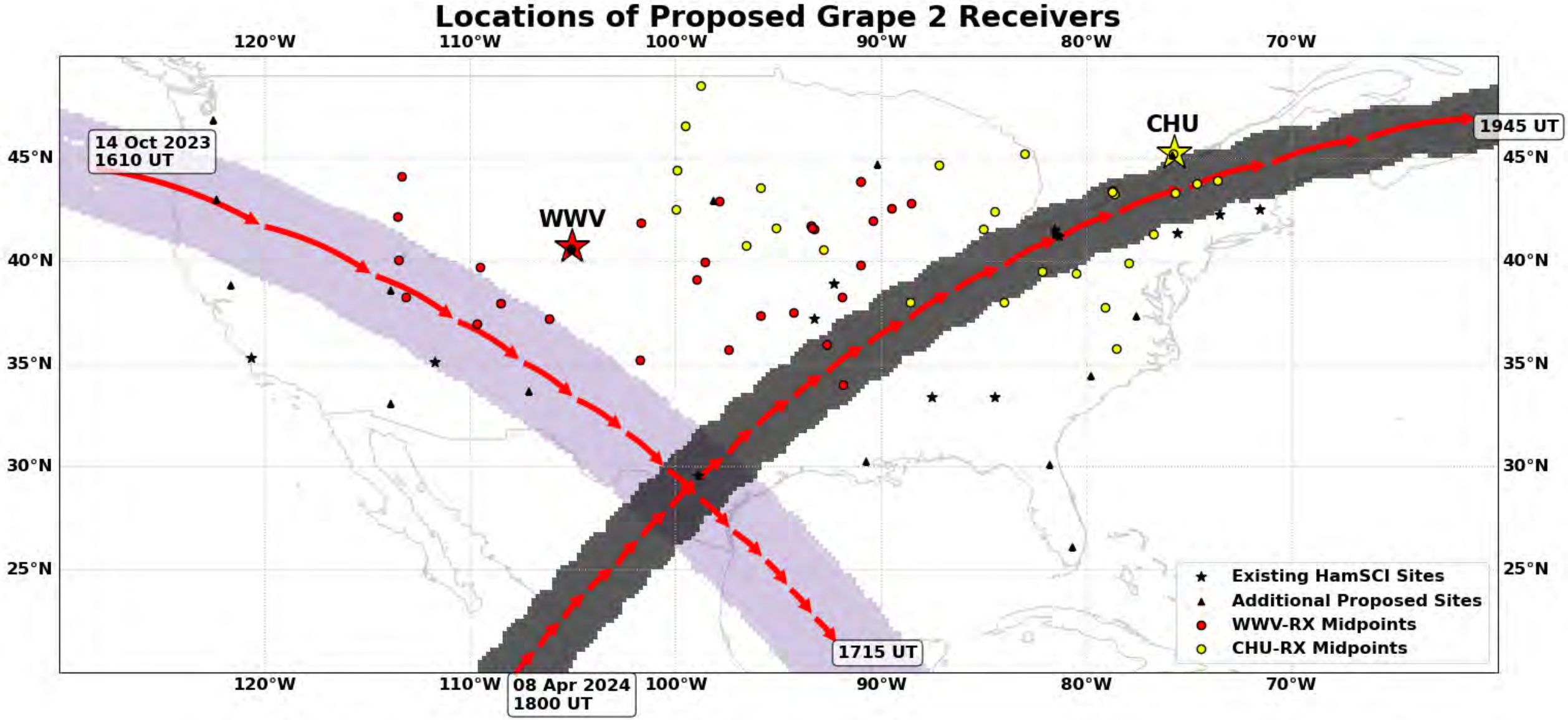


RF figure by Dr. Kristina Collins KD8OXT, see [1]

GRAPE

- GPS disciplined oscillator to allow accurate measurement of Doppler shift from WWV/WWVH
- Inexpensive and distributable
- Performs well in bunches
- Version 2 will be able to monitor 3 HF channels at a time

Grape V2 prototype image by J. Gibbons N8OBJ, more information in [2]



Plot Generated by Nathaniel Frissell

Scientific Questions

- Dawn/Dusk variations
- Eclipse similarities and differences
- What can we observe for multipath and mode splitting in the signal path?

Scientific Questions

1. How do dawn and dusk ionospheric variability vary with local time, season, latitude, longitude, frequency, distance, and direction from the transmitter?
2. Is eclipse ionospheric response symmetric with regard to the onset and recovery timing?
3. How similar is the eclipse to the daily dawn and dusk terminator passage?
4. Would multipath HF mode-splitting in the post-eclipse interval be similar to dawn events?
5. Would the response be different for two eclipses?

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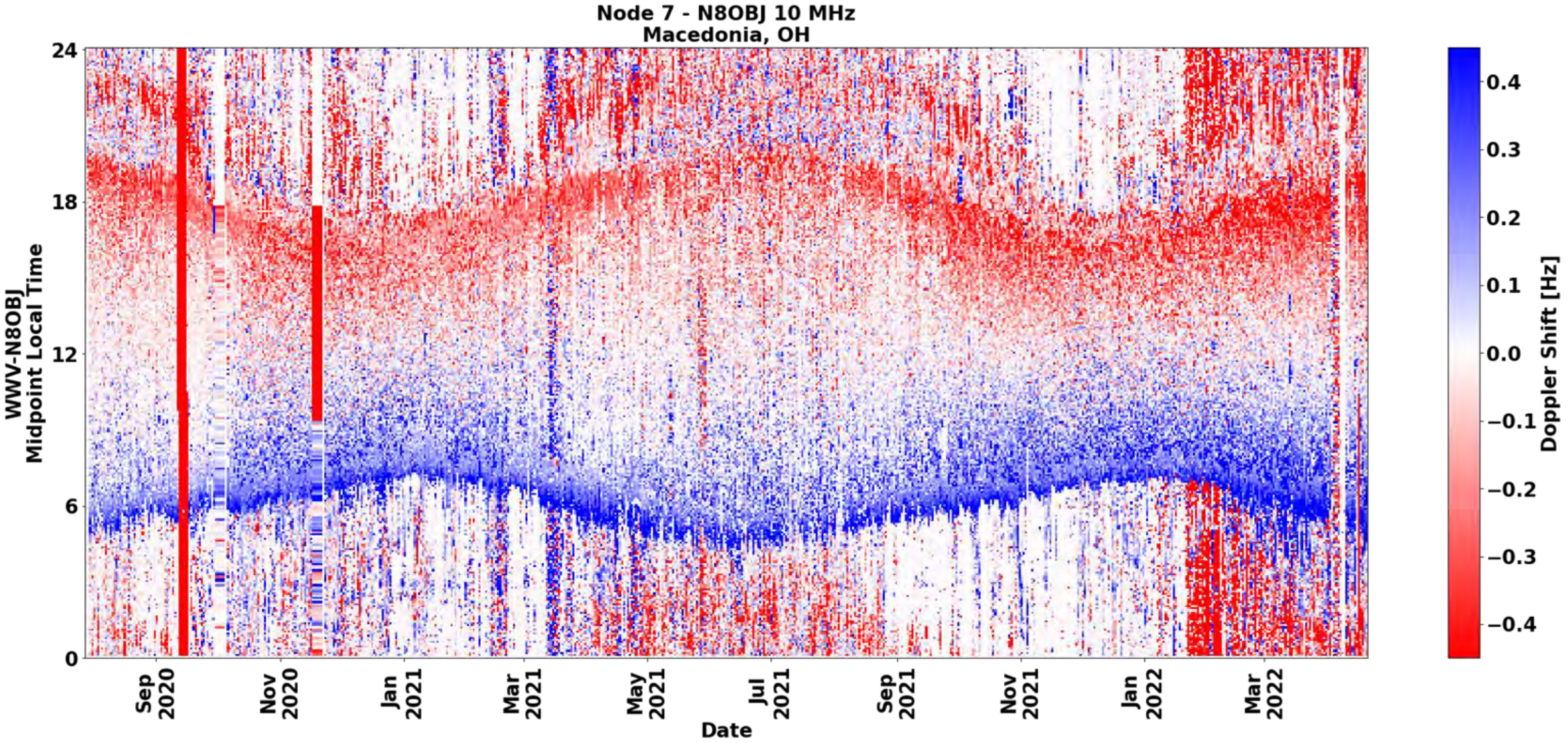
10 MHz WWV Data (N8OBJ, Macedonia OH)



Data from John Gibbons, N8OBJ

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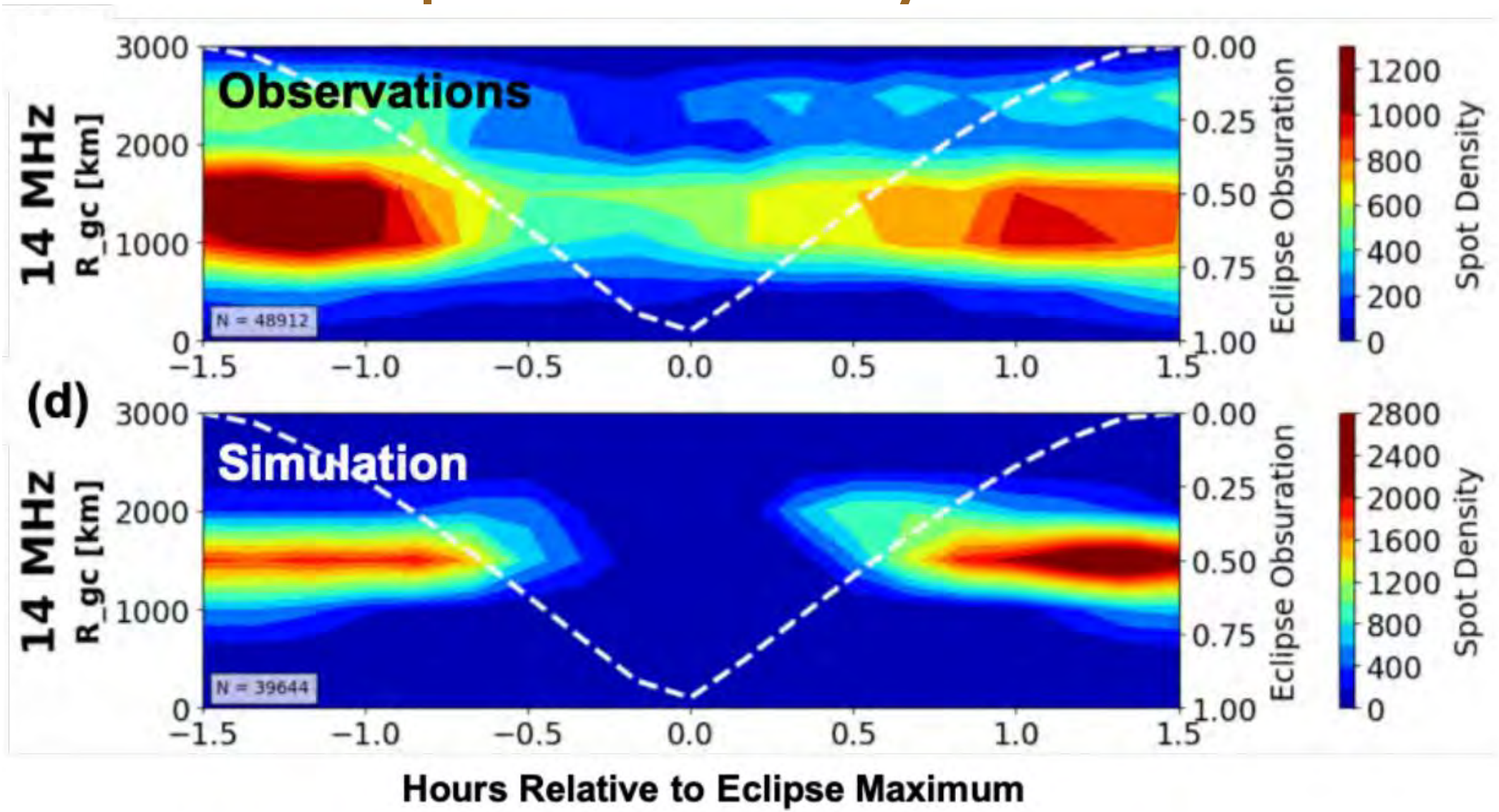
2017 Solar Eclipse QSO Party Data



Plots generated by Nathaniel Frissell, see [3]

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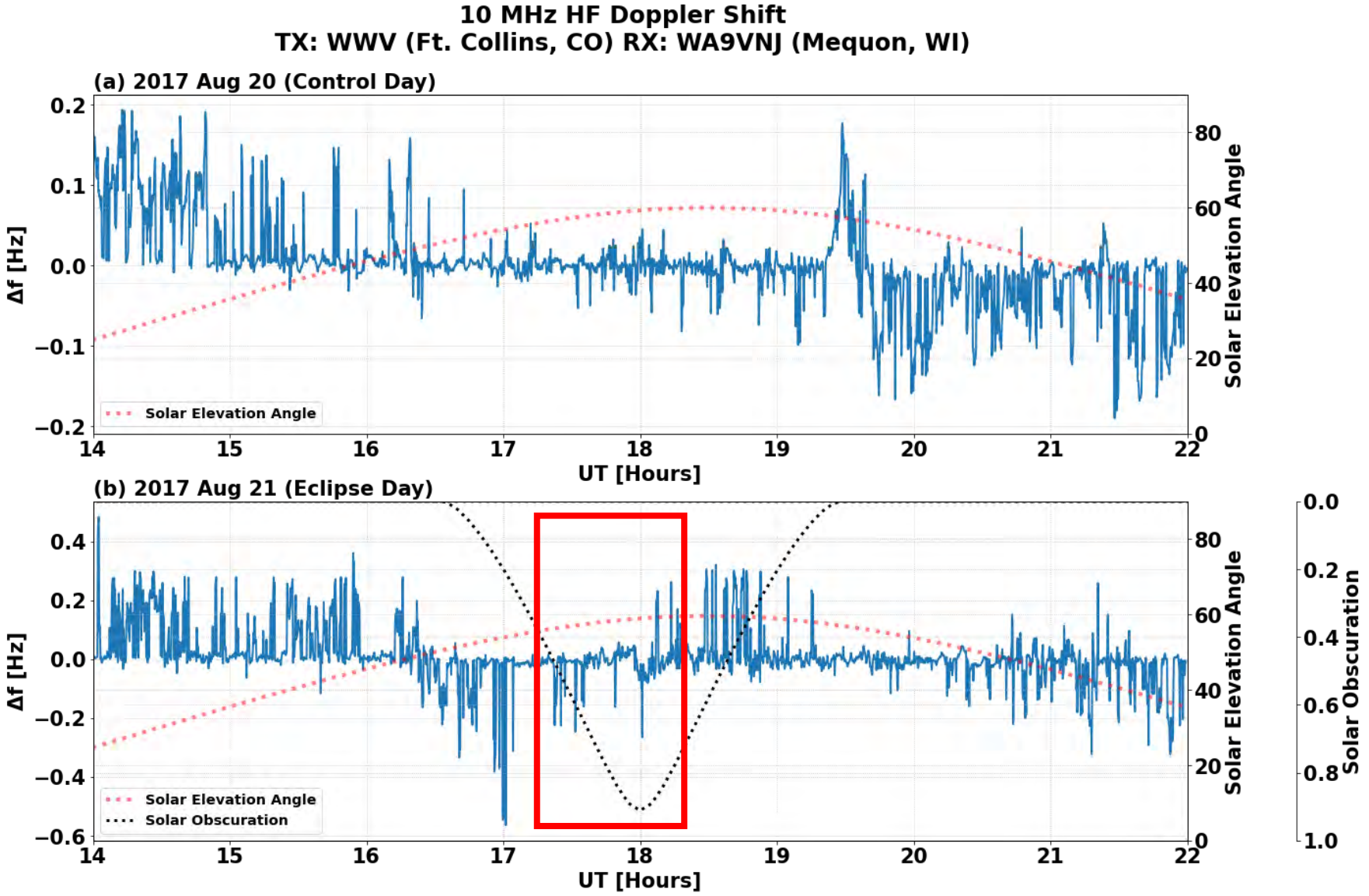
2017 Doppler Shift Data from WA9VNJ



Data from Steven Reyer, WA9VNJ

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Multipath

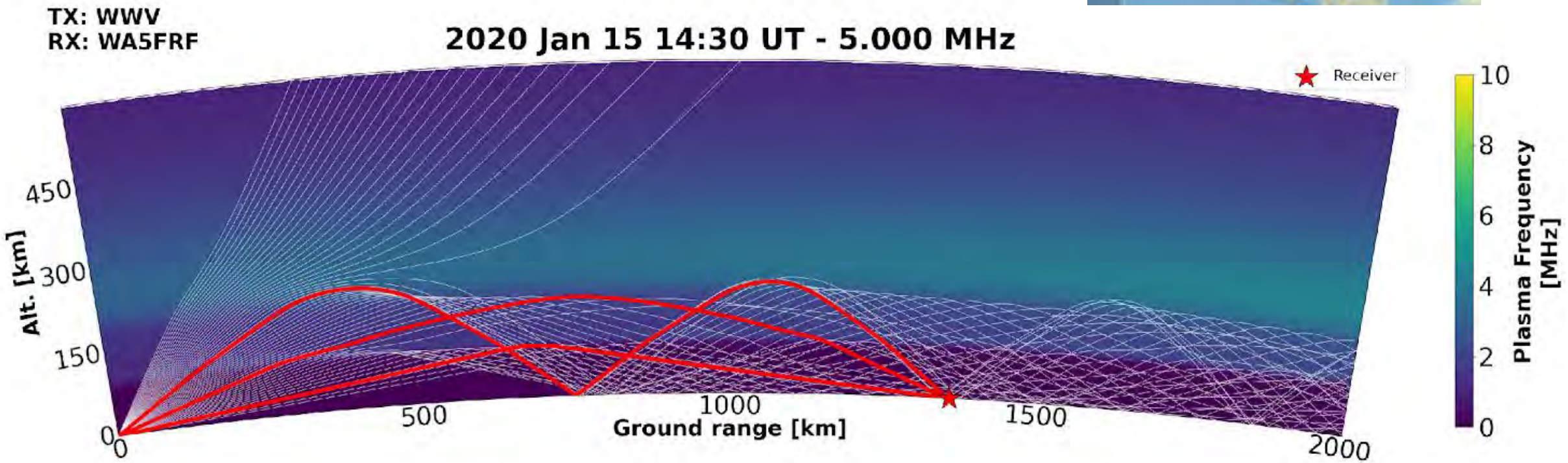
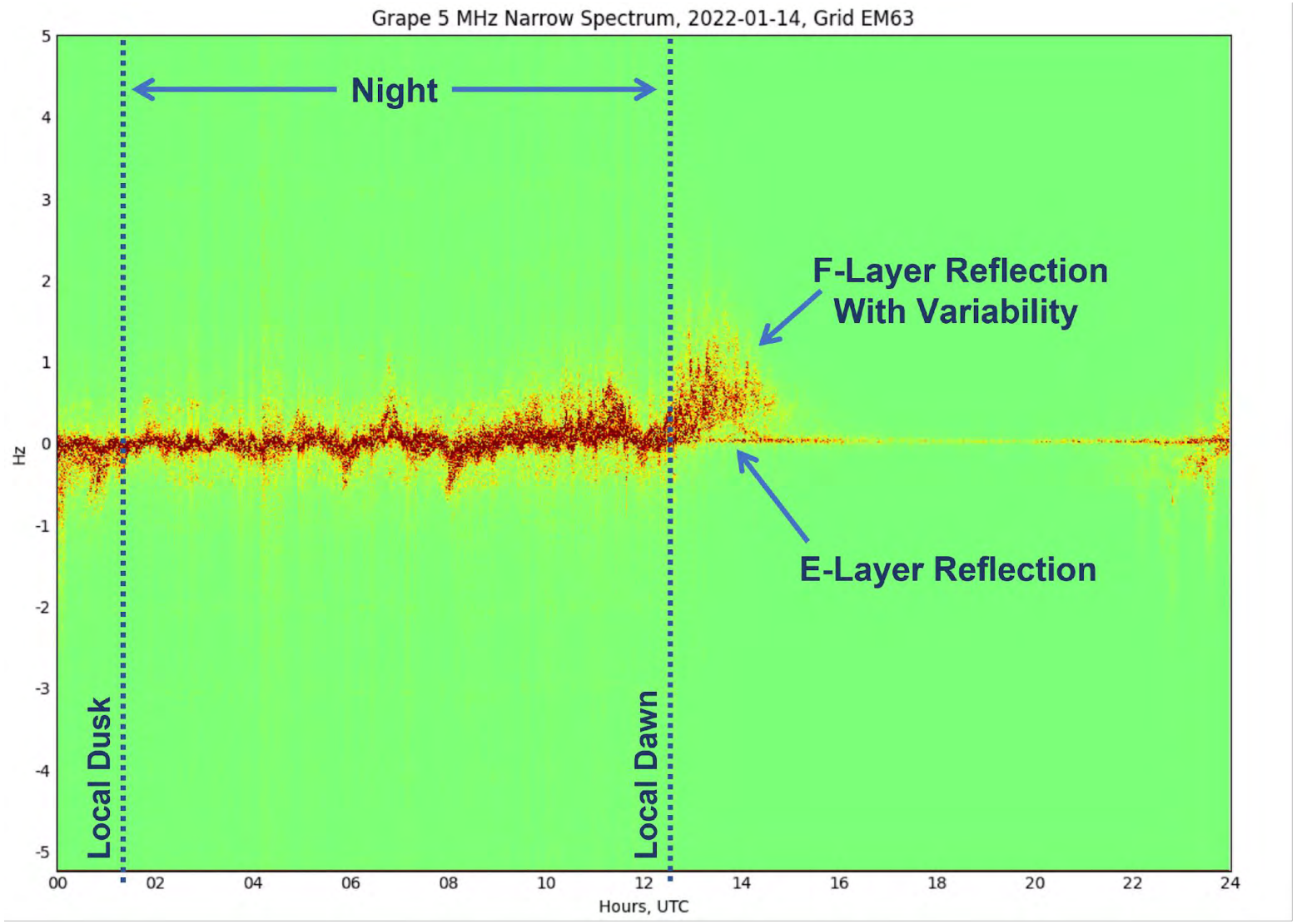


Image by Nathaniel Frissell

5 MHz WWV Doppler Shift Recordings (AB4EJ)



Data from Bill Engelke AB4EJ

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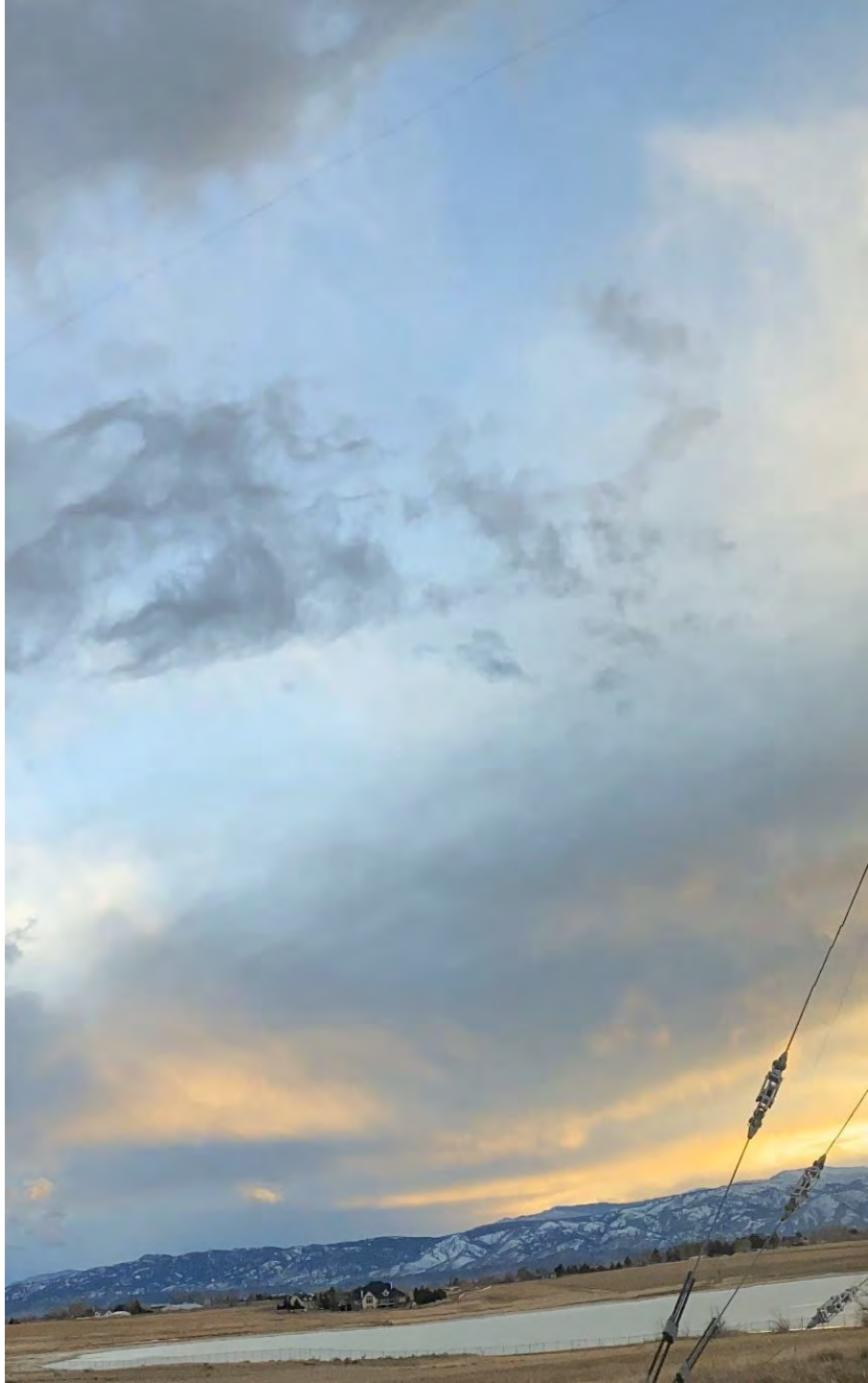
Project Timeline

- 2023: Grape Construction and Distribution
- 2023 October: annular eclipse across western United States
- 2024 April: total solar eclipse across eastern United states
- 2024: Data Processing



2023 and 2024 Solar Eclipses

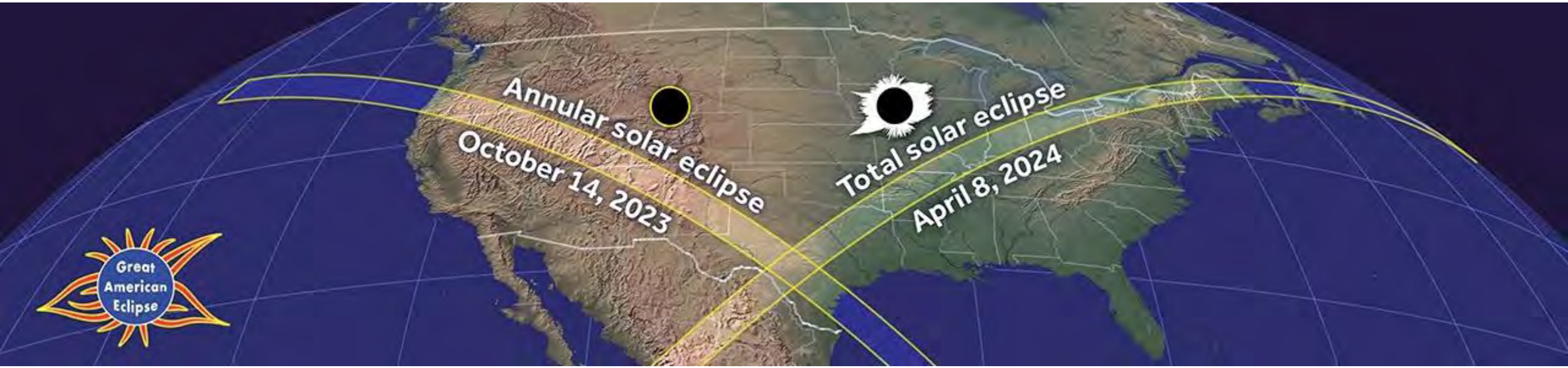


Image from Michael Zeiler, GreatAmericanEclipse.com

Broader Impacts of the Work

- Public outreach with the amateur radio community
- Accessible citizen science for radio enthusiasts
- A distributed array of small instruments (DASI)
- Graduate Students at Scranton and Case Western

Acknowledgement and Disclaimer

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Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Personal Space Weather Station Team

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- Devin Diehl
- Rachel Frissell W2RUF
- Cuong Nguyen KC3UAX
- Gerard Piccini KC3ZHK
- Veronica Romanek KC2UHN
- Jonathan Rizzo KC3EEY
- Simal Sami KC3UAW
- Bob Spalletta KC3QOB
- Nisha Yadav
- Dev Joshi KC3PVE (Now at Iowa)

Responsibilities
- Lead Institution
- HamSCI Lead
- Radio Science Lead

TAPR & Zephyr Engineering
- **Scotty Cowling WA2DFI (Chief Architect)**
- Tom McDermott N5EG (RF Board)
- John Ackerman N8UR (Clock Module)
- David Witten KD0EAG (Magnetometer)
- Jules Madey K2KGJ (Magnetometer)
- David Larsen KV0S (FPGA Code/Website)

Responsibilities
- TangerineSDR (High Performance)
- Ground Magnetometer

University of Alabama
- **Bill Engelke AB4EJ (Chief Architect)**
- Travis Atkison (PI)

Responsibilities
- Central Database
- Central Control Software
- Local Control Software

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Case Amateur Radio Club W8EDU
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- **David Kazdan AD8Y**
- **John Gibbons N8OBJ**
- Christian Zorman (PI)
- Rachel Boedicker AC8XY
- Skylar Dannhoff KD9JPX

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- Low Cost PSWS System

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Dartmouth College
- David McGaw N1HAC

New Jersey Institute of Technology
- **Hyomin Kim KD2MCR (PI)**
- Gareth Perry KD2SAK
- Diego Sanchez KD2RLM
- Andy Gerrard KD2MCQ

Responsibilities
- Ground Mag Oversight & Testing
- Science Collaborators

Citations

[1] Collins, K., Montare, A., Frissell, N. A., & Kazdan, D. (2021). Citizen Scientists Conduct Distributed Doppler Measurement for Ionospheric Remote Sensing. IEEE Geoscience and Remote Sensing Letters. doi: 10.1109/LGRS.2021.3063361

[2] Gibbons, J., Collins, K., Kazdan, D., & Frissell, N. (2022). Grape Version 1: First prototype of the low-cost personal space weather station receiver. HardwareX, 11, e00289. doi: 10.1016/J.OHX.2022.E00289

[3] Frissell, N. A., Katz, J. D., Gunning, S. W., Vega, J. S., Gerrard, A. J., Earle, G. D., . . . Silver, H. W. (2018). Modeling Amateur Radio Soundings of the Ionospheric Response to the 2017 Great American Eclipse. Geophysical Research Letters, 45(10), 4665–4674. doi: 10.1029/2018GL077324

Questions?

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HamSCI

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Join us 9 am EST on Thursday's for the Grape group telecon!