Eclipse project background information

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This document provides some helpful background information on the technology that we will be deploying to study the total solar eclipse occurring on April 8, 2024.

Atmospheric research

The upper atmosphere—both the neutral, terrestrial section near the Earth and the higher, ionized portion (the ionosphere)—are very active areas of study by the scientific community. In order to better understand the dynamics of these systems, remote sensing technology such as radar are used to measure physical parameters that are 40–200 miles above the Earth's surface. MIT Haystack Observatory is developing two new radar technologies to measure specific elements of the upper atmosphere and the ionosphere. Both of systems use what's called *multiple-input multiple-output (MIMO)* radar techniques and technology that will require multiple nodes in a network of sensor system.[1]

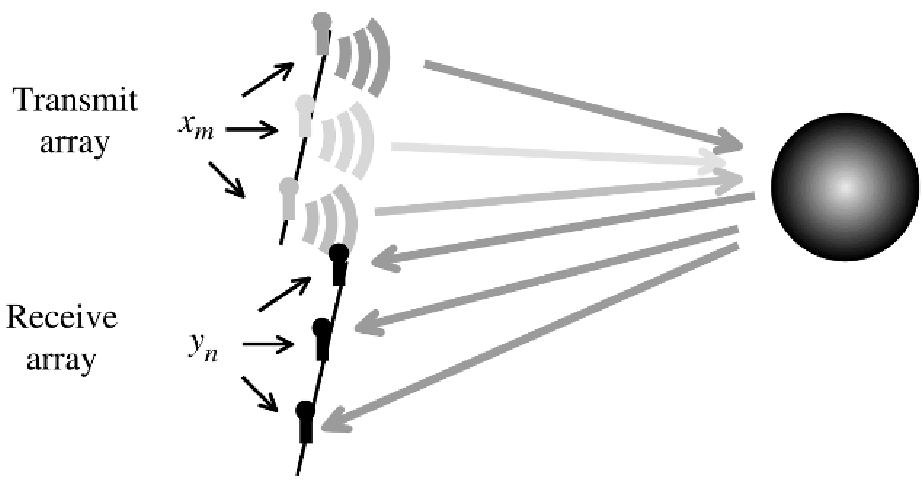

Figure 1: Diagram of a MIMO radar system with separate transmitters and receivers illuminating a target area. From [1].

Haystack's eclipse radar systems

Zephyr is a radar system that measures meteors (also known as shooting stars) to measure winds at the edge of space, 50–60 miles above the Earth's surface. These are just like the regular winds we experience every day, but much higher in the atmosphere. Tiny micrometeoroids—space dust less than half an inch in size—are constantly entering the Earth's atmosphere and burning up. Because of their small size, the meteors are not visible, but the meteoroids leave a trail of ions and electrons that reflect radar signals. The key behavior for our study is that these meteor trails move with the wind and act like a tracer, allowing Zephyr to measure winds by observing the meteors. With enough meteor observations, we can estimate the winds in three-dimensional space as they change over time. Very little is known about what these upper atmospheric winds look like in response to an eclipse, and we expect to learn completely new things in this study!

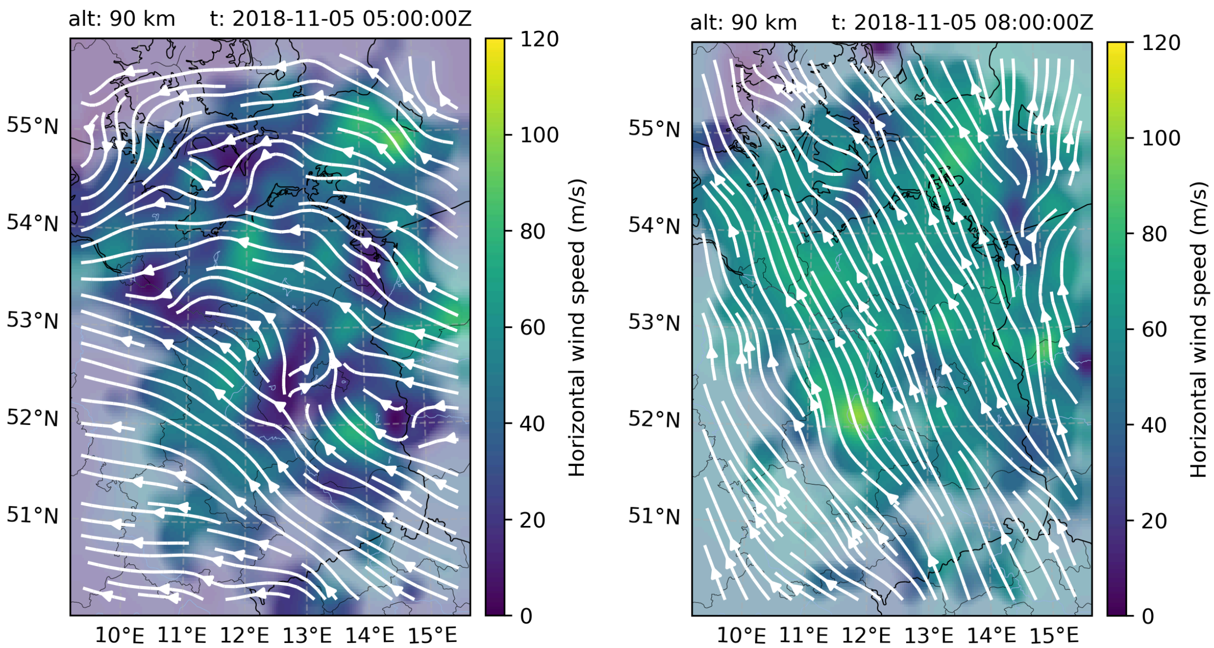

Figure 2: Winds at 90 km altitude (~56 miles above the Earth's surface) over Germany estimated at two different times. The streamlines show wind direction, and color indicates speed. Meteor radars are one of the few systems that can make measurements at these horizontal scales, and there is still a lot we don't know about winds in the upper atmosphere.

EMVSIS, which stands for Electro-Magnetic Vector Sensor Ionospheric Sounder, will record reflections of signals at different frequencies to measure the electron density (number of charged particles per unit volume) and ion velocity (the motion of the charged particles). The specific radio technique at the heart of this system has been used for more than 100 years to study the ionosphere. The EMVSIS system will be applying a number of new technologies and techniques to create measurements with lower size, weight, and power requirements.

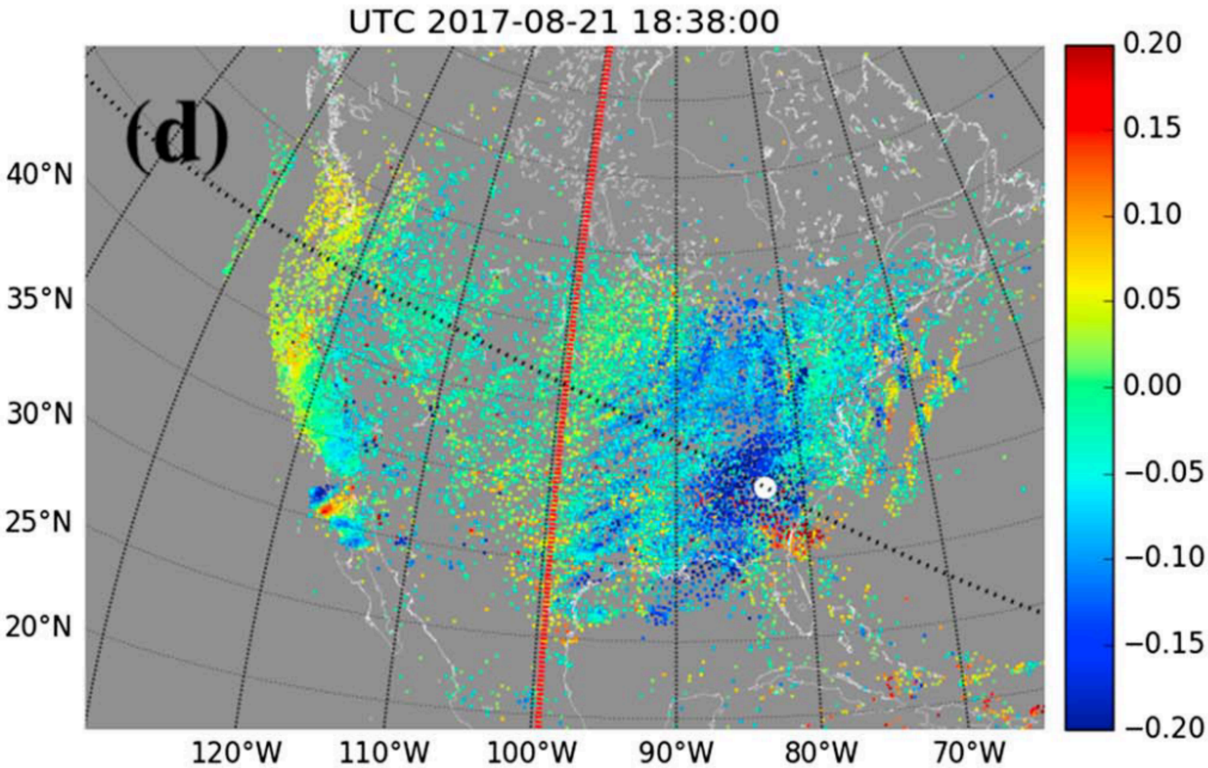

Figure 3: GPS Total Electron Content measurement from total solar eclipse in 2017. Note the wave pattern following the shadow of the Sun (white circle on the dotted line). These bow waves in the ionosphere occur from the sun's shadow moving at supersonic speeds. From [2].

The total solar eclipse on April 8, 2024, will give scientists a unique opportunity to study the upper atmosphere and ionosphere. As the Moon blocks out the Sun over a small area of the Earth, this event can induce a number of interesting behaviors of the atmosphere and ionosphere. We will be deploying transmitters and receivers for both systems and will use the 2024 eclipse as an opportunity to test these systems and get new measurements of our upper atmosphere and ionosphere.

References

[1] J. Li and P. Stoica, Eds., *MIMO Radar Signal Processing*. Hoboken, NJ, USA: John Wiley & Sons, Inc., 2008. https://doi.org/10.1002/9780470391488

[2] S. R. Zhang, P. J. Erickson, L. P. Goncharenko, A. J. Coster, W. Rideout, and J. Vierinen, “Ionospheric Bow Waves and Perturbations Induced by the 21 August 2017 Solar Eclipse,” *Geophysical Research Letters*, vol. 44, no. 24, p. 12,067–12,073, Dec. 2017, https://doi.org/10.1002/2017GL076054