2017 Total Solar Eclipse across North America

CEDAR 2017 Keystone
June 20, 2017

P. J. Erickson, L. P. Goncharenko, S.-R. Zhang, A. J. Coster
MIT Haystack Observatory
and many other CEDAR community members

Historical Eclipse Studies

APRIL 1, 1939 PHYSICAL REVIEW VOLUME 55

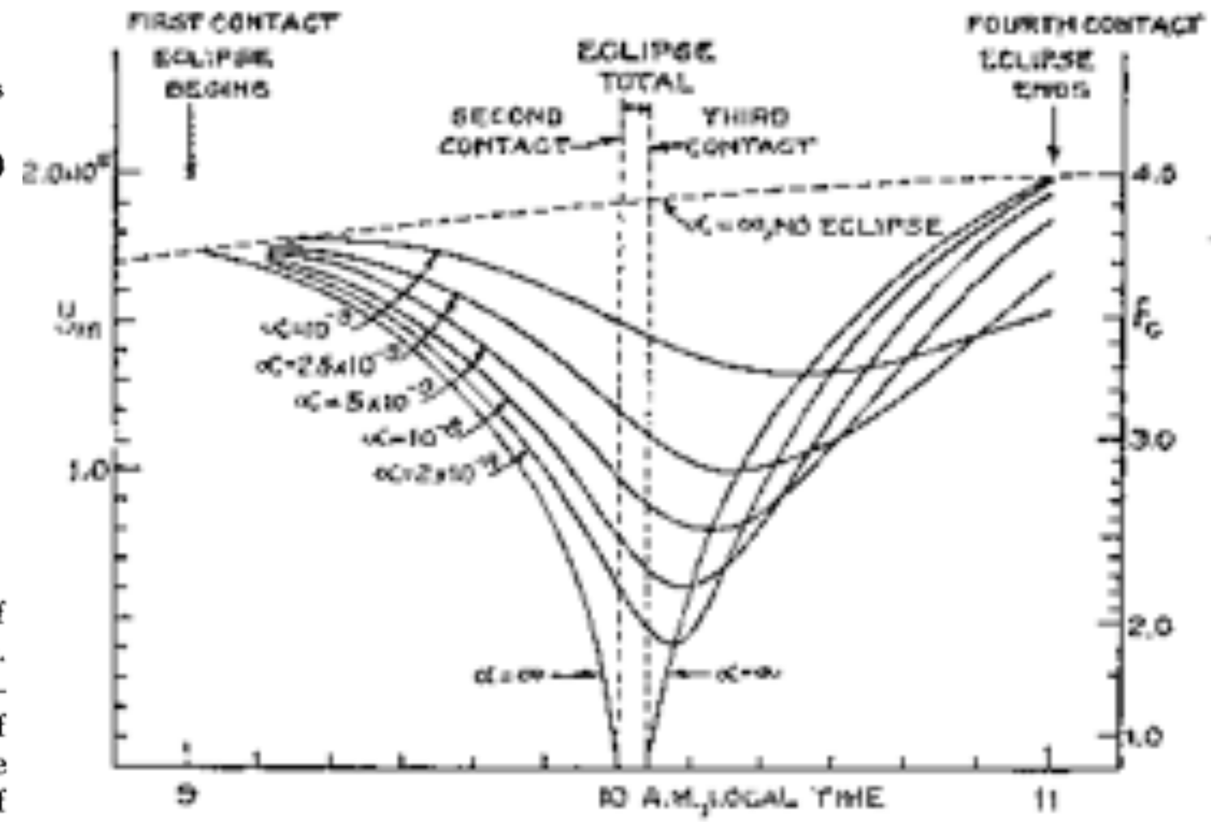
The E Region of the Ionosphere During the Total Solar Eclipse of October 1, 1940

E. O. HULBURT
Naval Research Laboratory, Washington, D. C.
(Received February 16, 1939)

It is pointed out that ionospheric observations during the total solar eclipse of October 1, 1940, visible in northern Brazil, may provide data for an exacting test of the theory of solar radiation origin of the E region and may yield a precise value of the ionic recombination coefficient α that occurs in the theory. To this end E region ionization curves are worked out for various assumed values of α during the eclipse.

LET y_m be the maximum-with-height value of the equivalent electron density of the E region of the ionosphere and let the recombination coefficient α of the ionization be proportional to y_m^2. In the preceding paper[1] it was shown that the observed variation of y_m during the daylight hours was in close agreement with the theory that the ionization was caused by solar radiation absorbed exponentially in a relatively quiet terrestrial atmosphere. A value for α of 2×10^{-8}

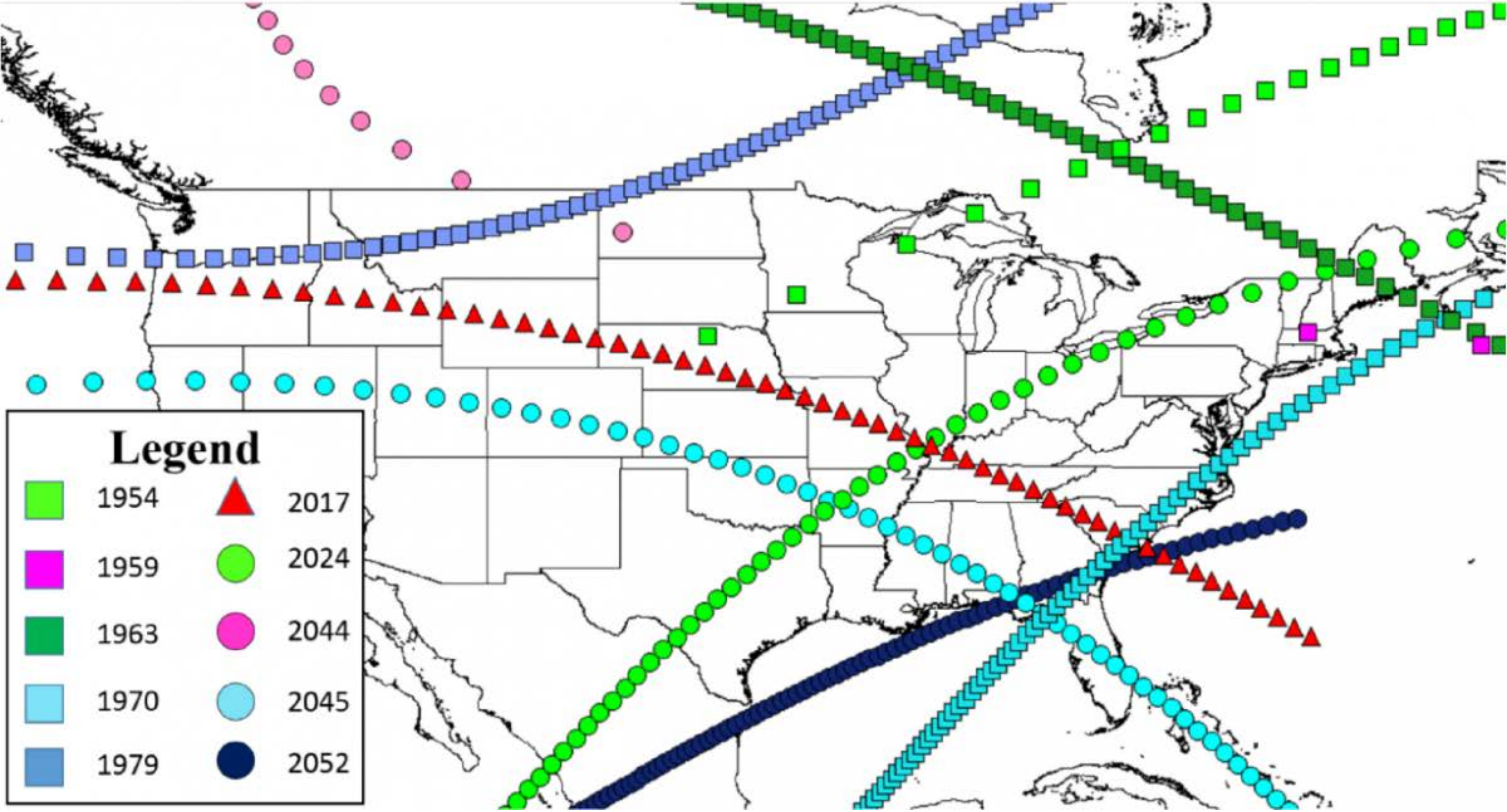
In Fig. 1 are given y_m curves for the period of the eclipse calculated for various values of α. In order to make the calculations, eclipse conditions were assumed that approximate those of the actual eclipse. Exact calculations for the actual eclipse can be made when the location of the observing station is known. Assume that the station is at latitude 8° S and longitude 35° W, as near Pernambuco, and that the first, second, third and fourth contacts occur at 9, 10, 10.04



IG. 1. Theoretical ionization of E region at Pernambuco, Brazil, during the eclipse of October 1, 1940.

(D. Drob, NRL)

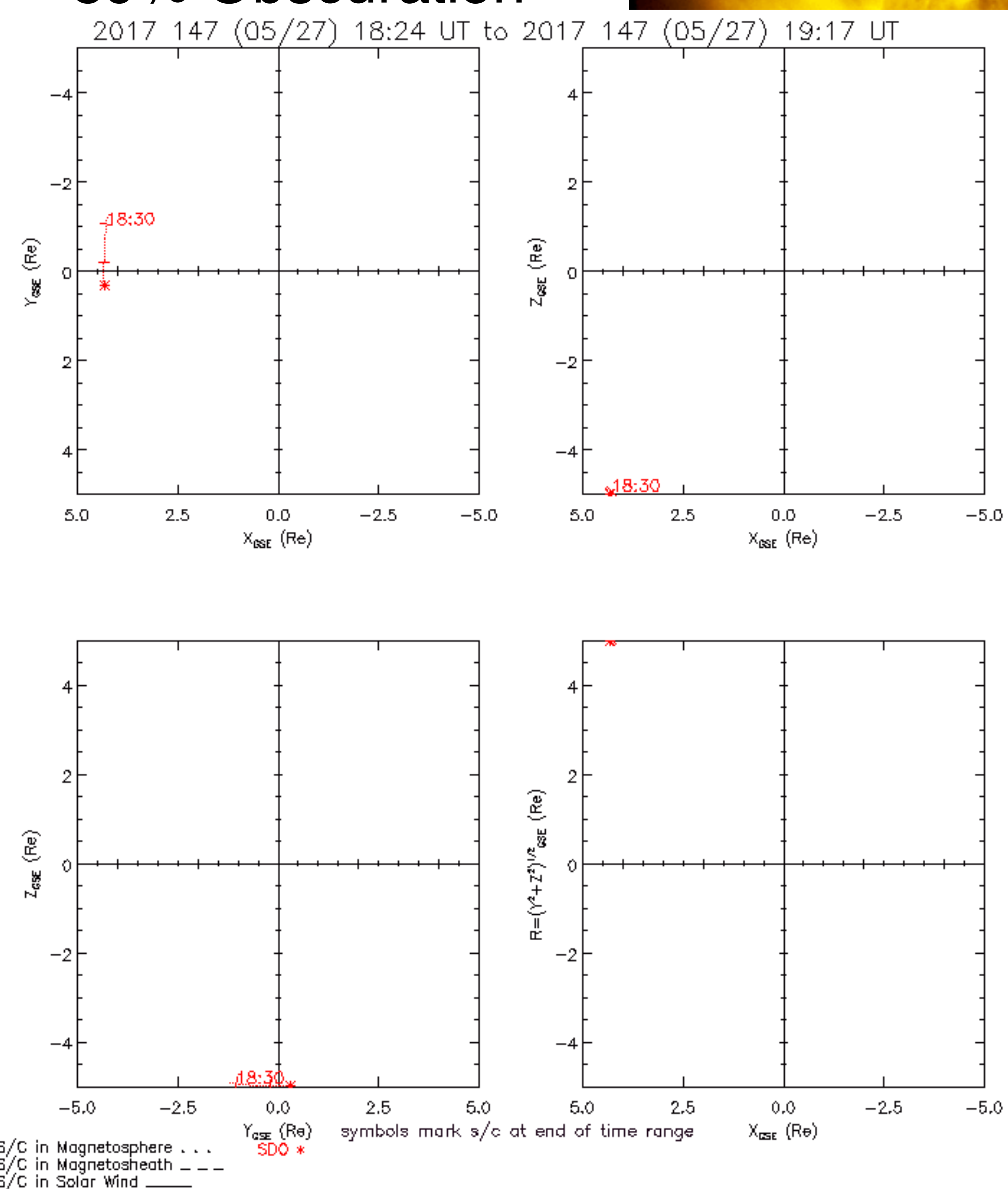
Map of All Eclipses over Continental US From 1950-2052

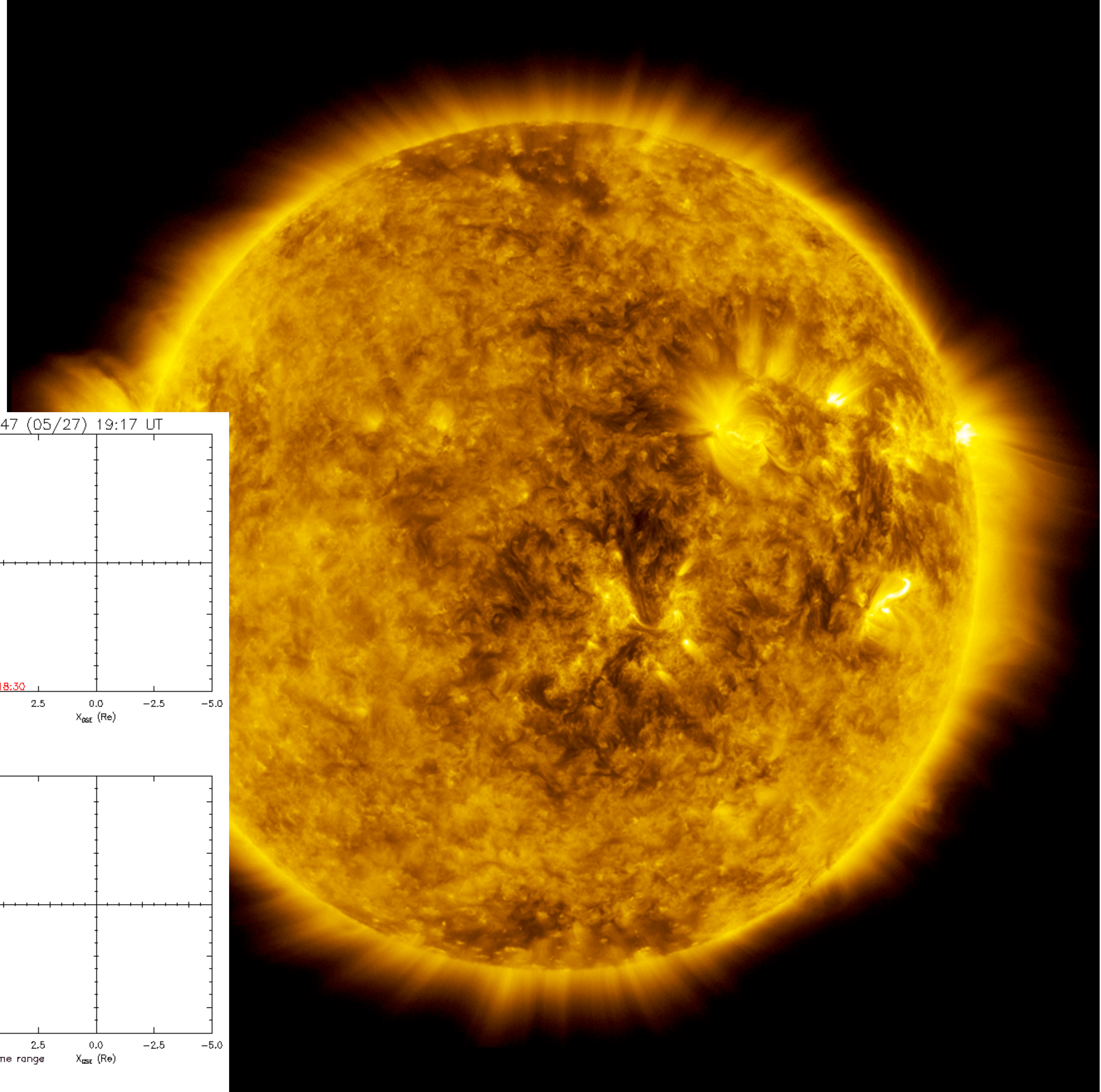


NASA
SDO
Partial eclipse
from space

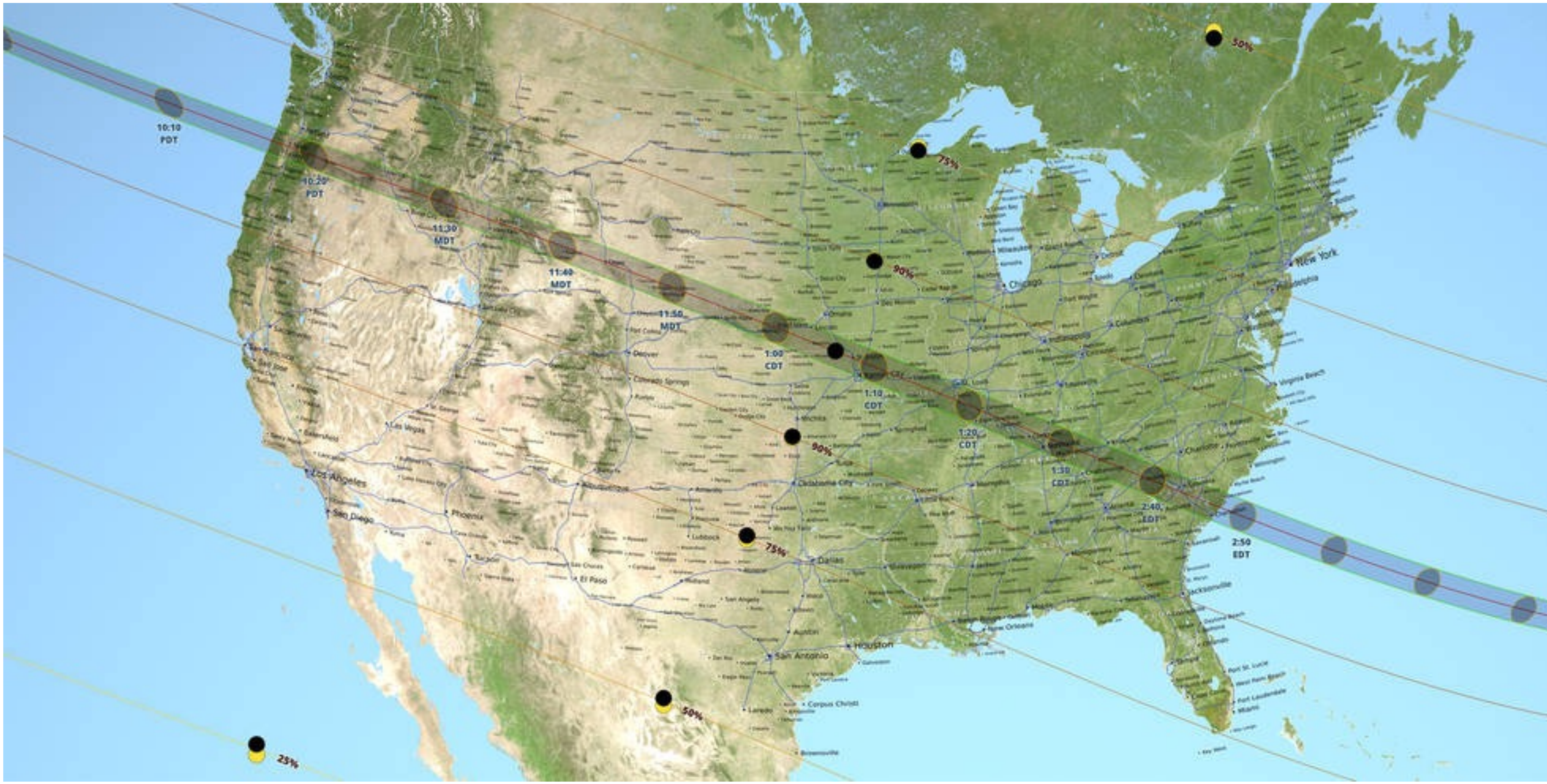
2017-05-27
1824 - 1917 UTC

89% Obscuration



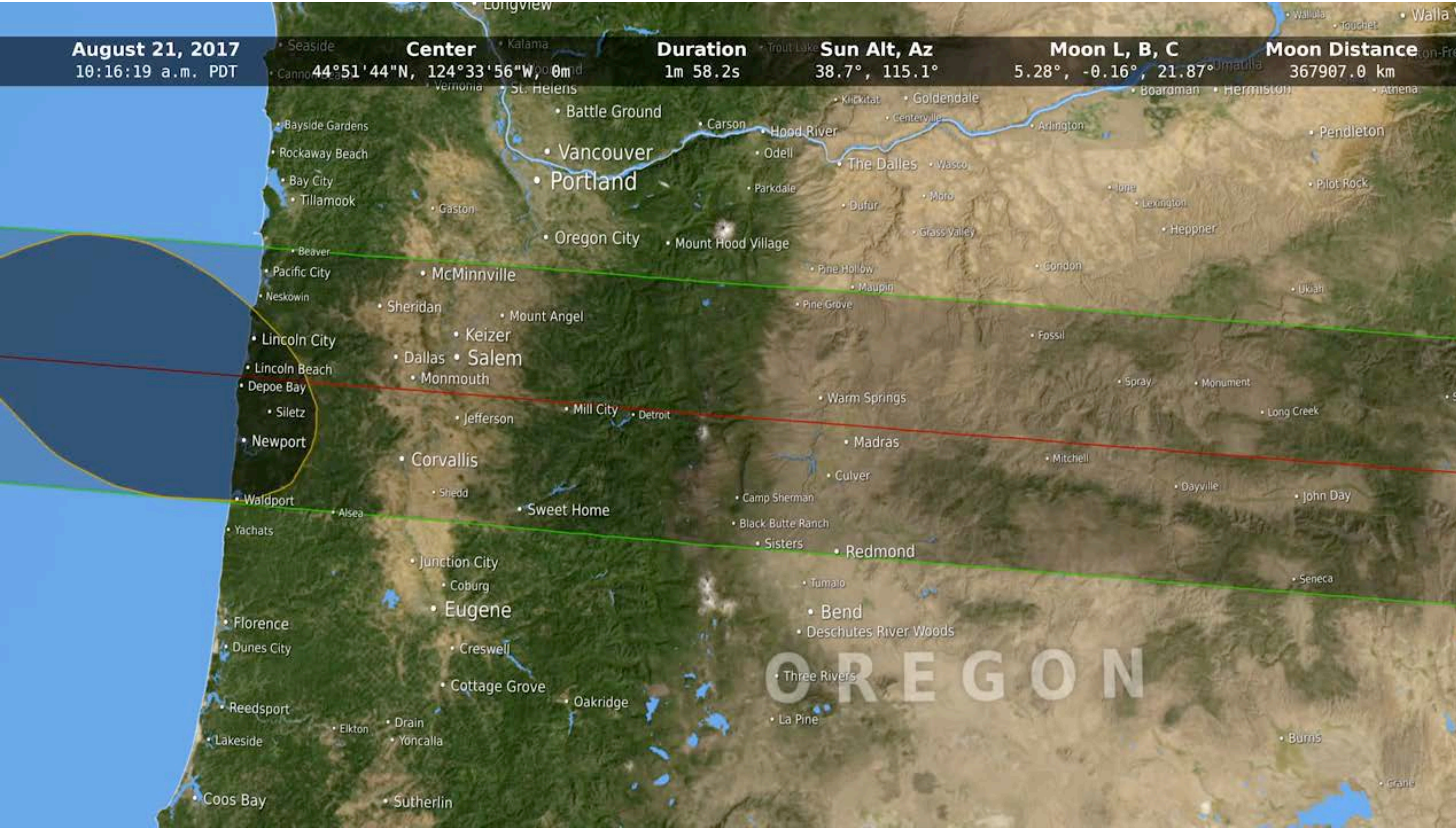


2017 Eclipse Track



(Ernie Wright, NASA GSFC)

2017 Eclipse Detailed Shadow Predictions



(Ernie Wright, NASA GSFC)

Eclipses: A Tool for Learning about Ionospheric Processes

SOLAR ECLIPSES AND IONOSPHERIC THEORY

H. RISHBETH

S.R.C., Radio and Space Research Station, Ditton Park, Slough, Bucks., England

(Received 1 March, 1968)

Steady-state continuity equations (NOTE: no transport here - but we know that happens)

$$dN/dt = E(t)\, q(t) - \alpha N^2$$ E layer

$$dN/dt = E(t)\, q(t) - \beta N$$ F2 layer

$E(t)$: Eclipse obscuration function

$q(t)$: Normal production function

$$q(z) = [\text{density}]\,[\text{cross-section}]\,[\text{flux at z}]$$
$$= n(z)\sigma[F_0 e^{-\tau(z)/\mu_0}],$$

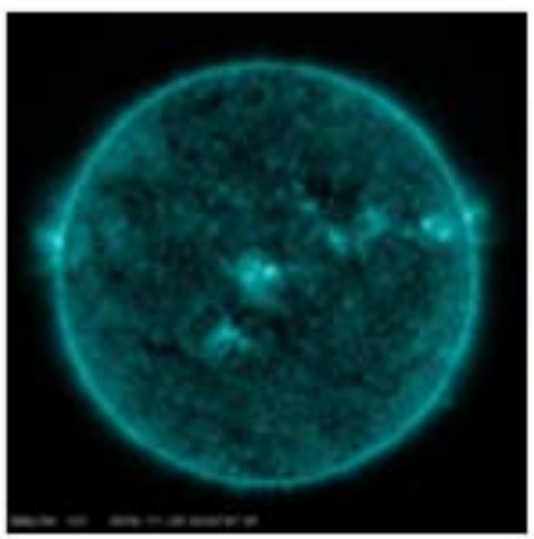
Observations during an eclipse offer a special opportunity for studying both the solar ionizing radiations and the earth's ionosphere. They are not ideal for this purpose. The ionospheric physicist might wish that the sun could be regarded as a constant, uniform source of ionizing radiation; but investigations of the sun show that it is not. The solar physicist would like to regard the ionosphere as a detector for ionizing radiation. But the ionosphere does not meet the basic requirements of a good detector: straightforward operation, reproduceability, and a linear or other convenient type of response.

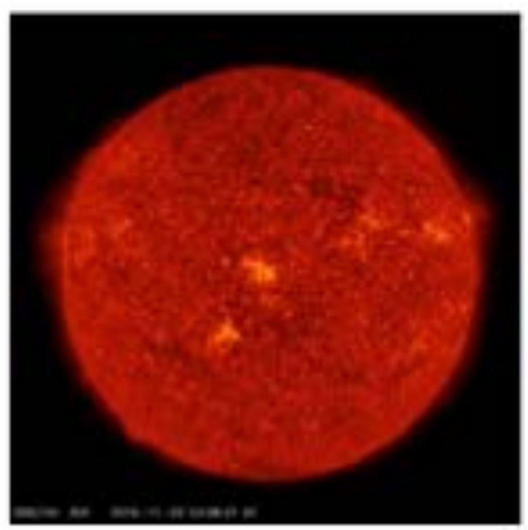
Modeling the EUV Changes during Eclipse

Modern Approach

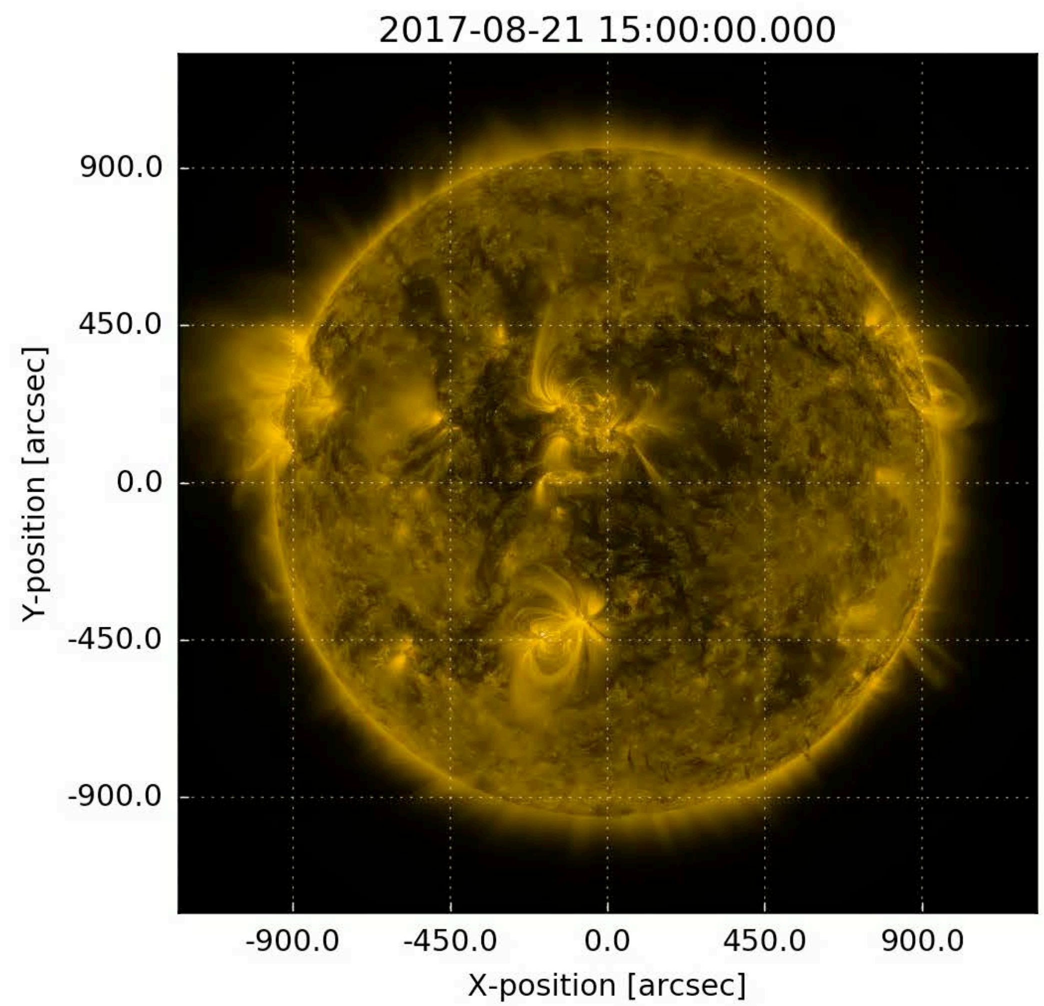
NASA Solar Dynamics Observatory
Atmospheric Imaging Assembly (AIA)
et al.

1 Minute images XUV to EUV



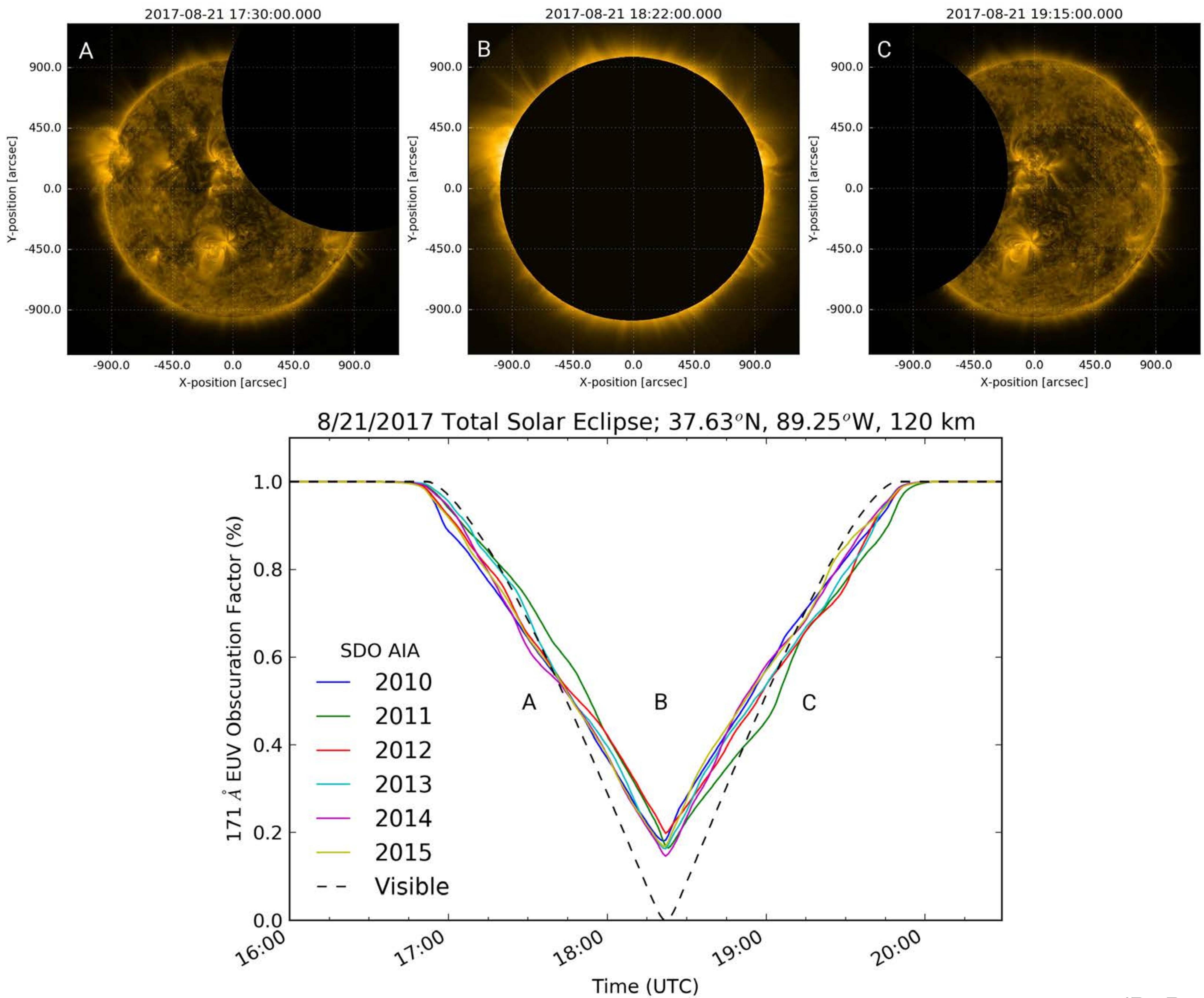


NOVAS + SunPy



(D. Drob, NRL)

Modeling the EUV Changes during Eclipse

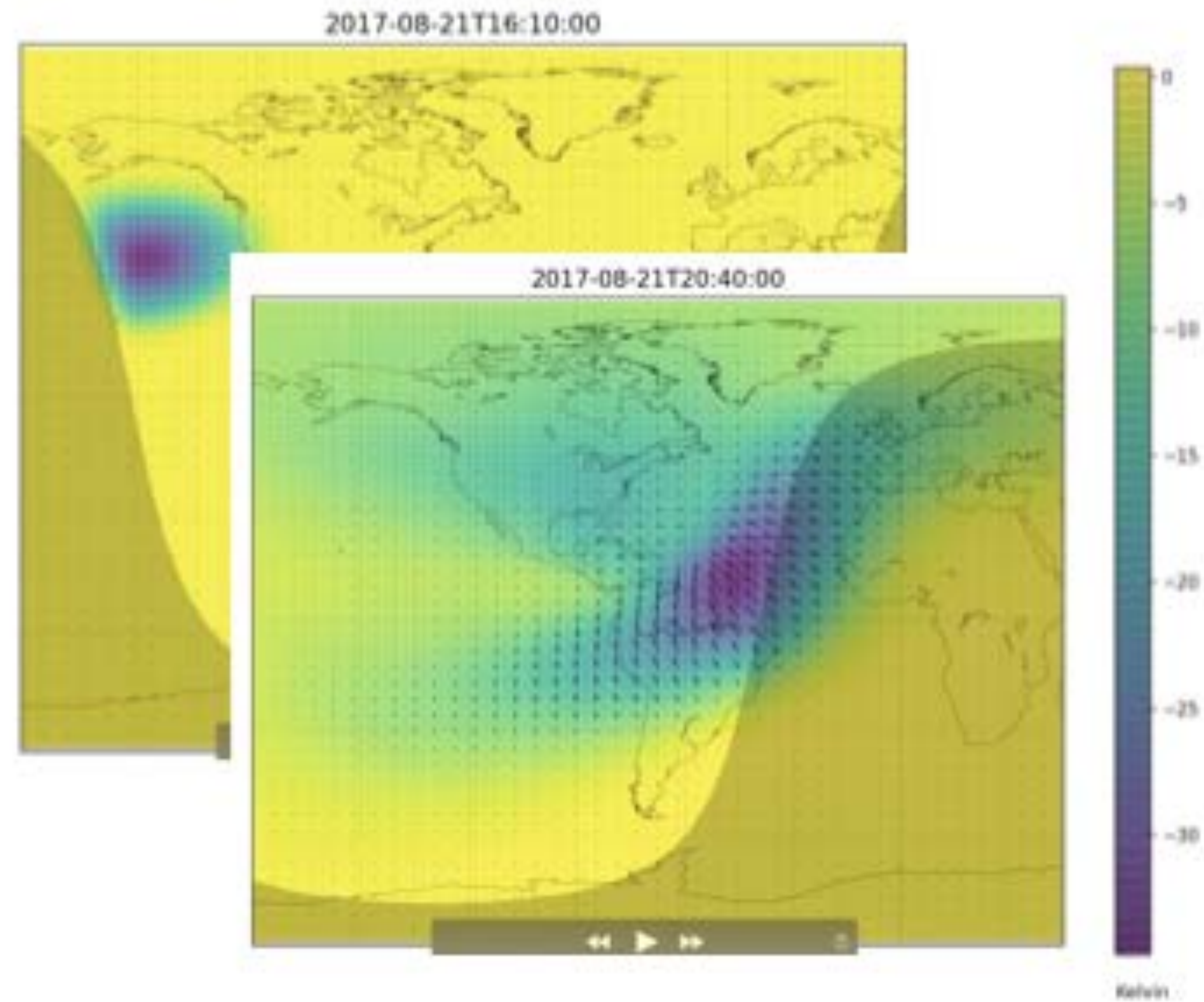


(D. Drob, NRL)

Theoretical Thermospheric Response

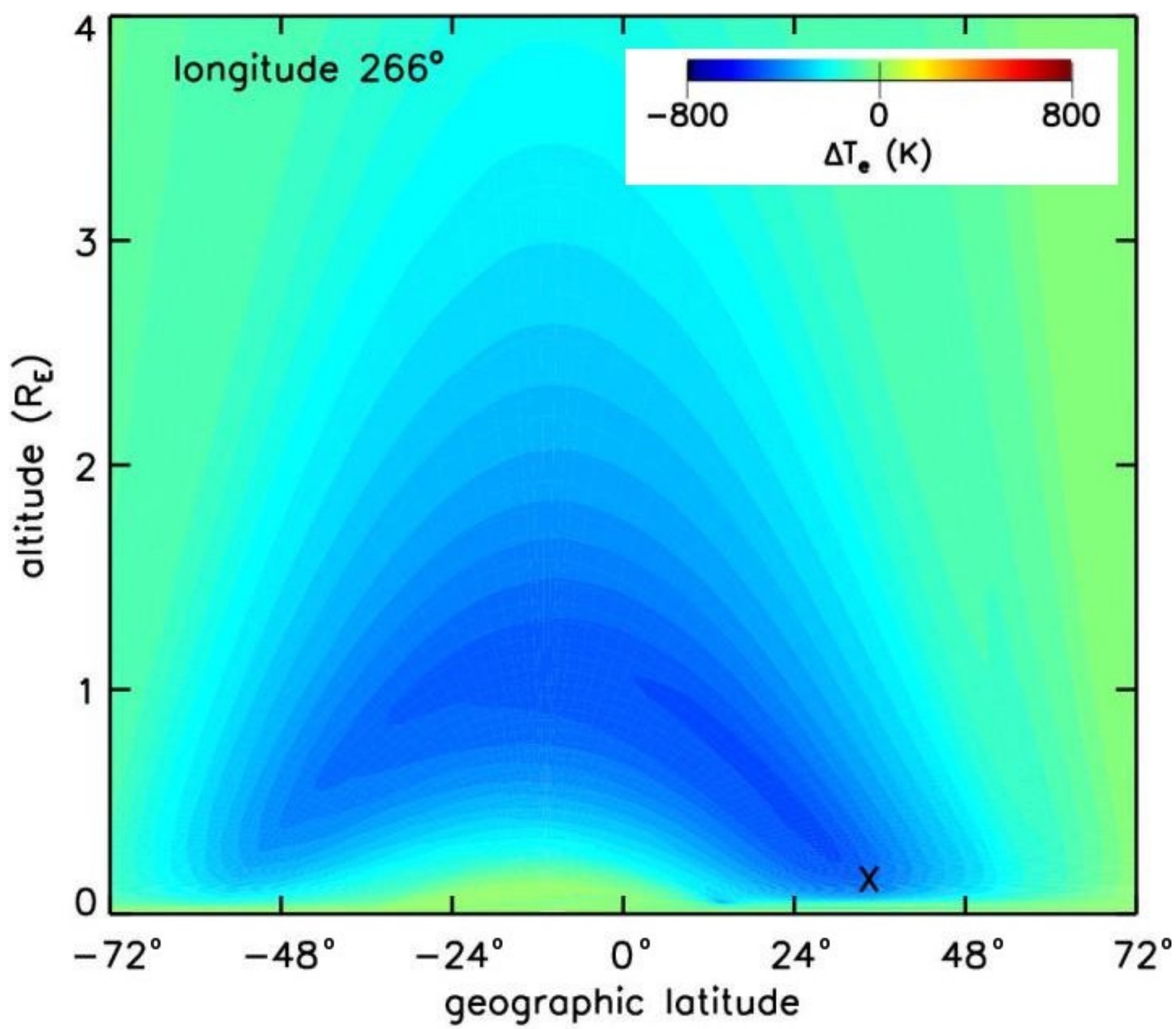
- NCAR TIMEGCM
  2.5 x 2.5 resolution
  15 second time step
- Apply 4d masks to all heating and photoproduction rates
- Compute difference fields between the eclipse and control runs
- Results x2 TIEGCM calculations (see Roble at al., 1984; 1986)

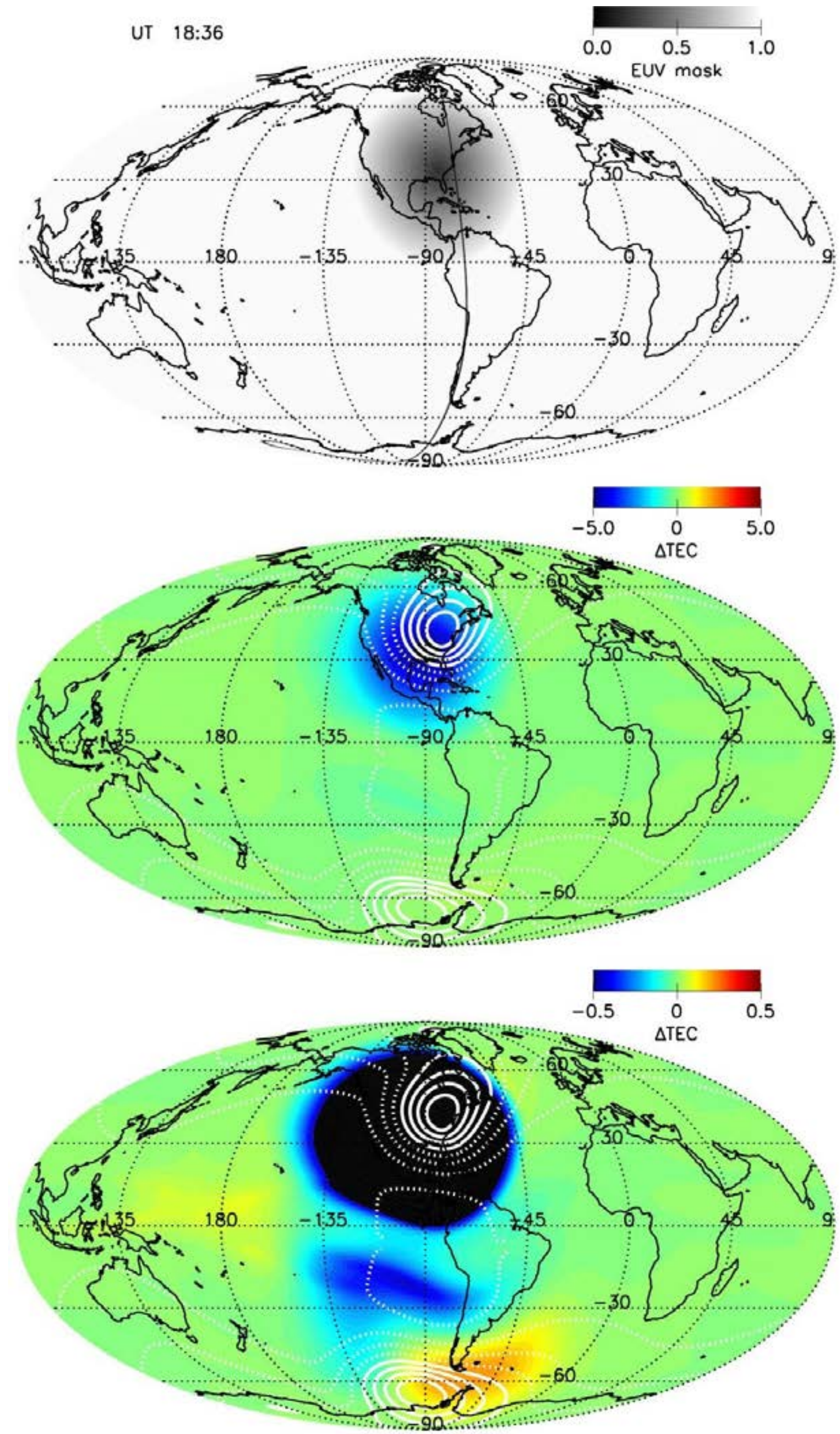
T'_n, U'_n, V'_n, W'_n @ 500 km



(D. Drob, NRL)

Modeling Eclipse-Induced Changes in the Ionosphere, Plasmasphere, and Thermosphere

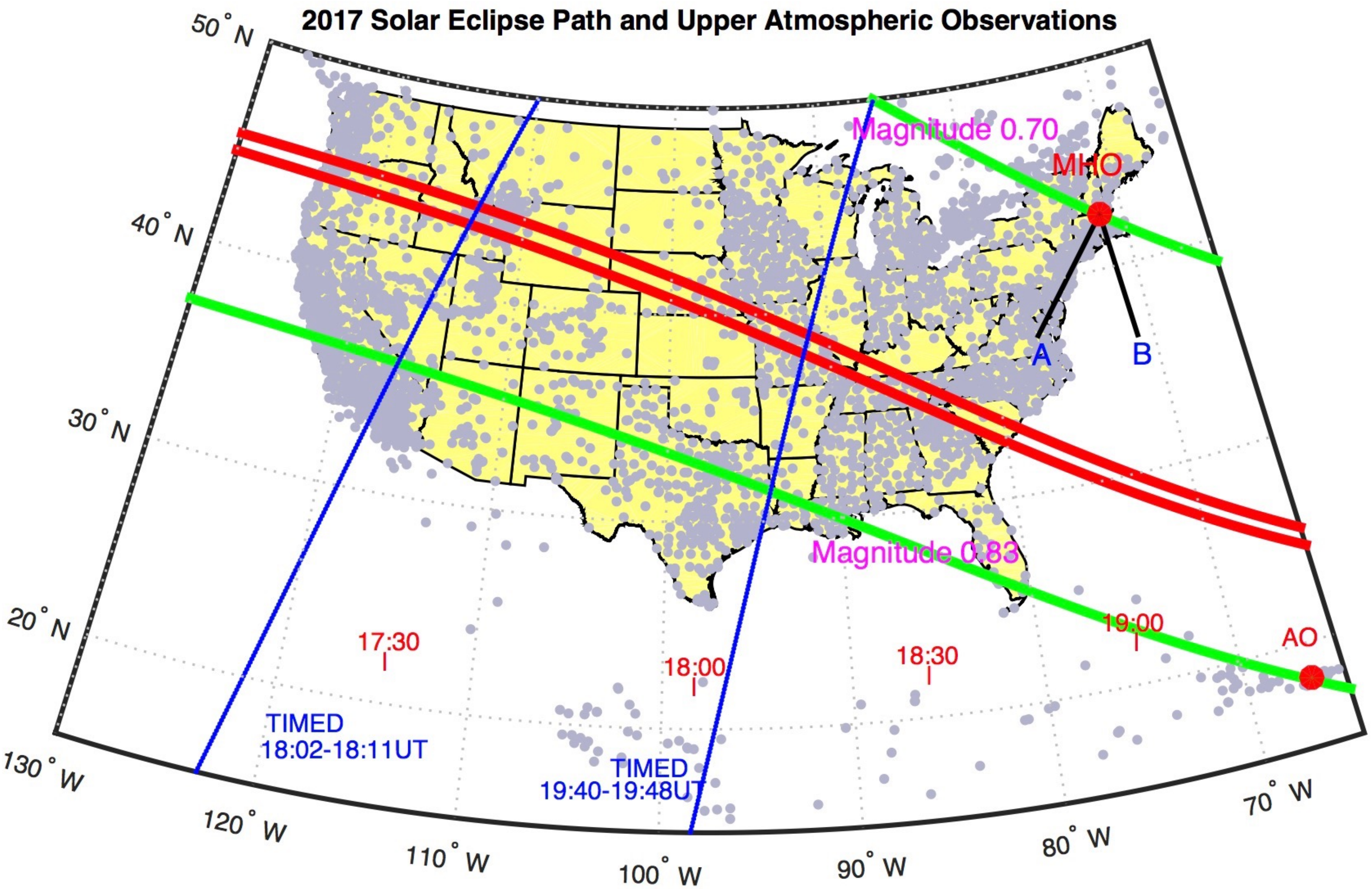




(J. Huba, NRL)

Solar Eclipse-Induced Changes in the Ionosphere over the Continental US

P. J. Erickson, A. J. Coster, S.-R. Zhang, L. P. Goncharenko
MIT Haystack Observatory



Instruments:

- GNSS
- Two ISRs
- TIMED
- DMSP

- What are the details of traveling ionospheric disturbances (TIDs) and atmospheric gravity waves (AGWs) triggered by the eclipse?
- What are the details of altitudinal and temporal ionospheric profile variations triggered by the eclipse?
- How widespread are spatial ionospheric variations associated with the eclipse?

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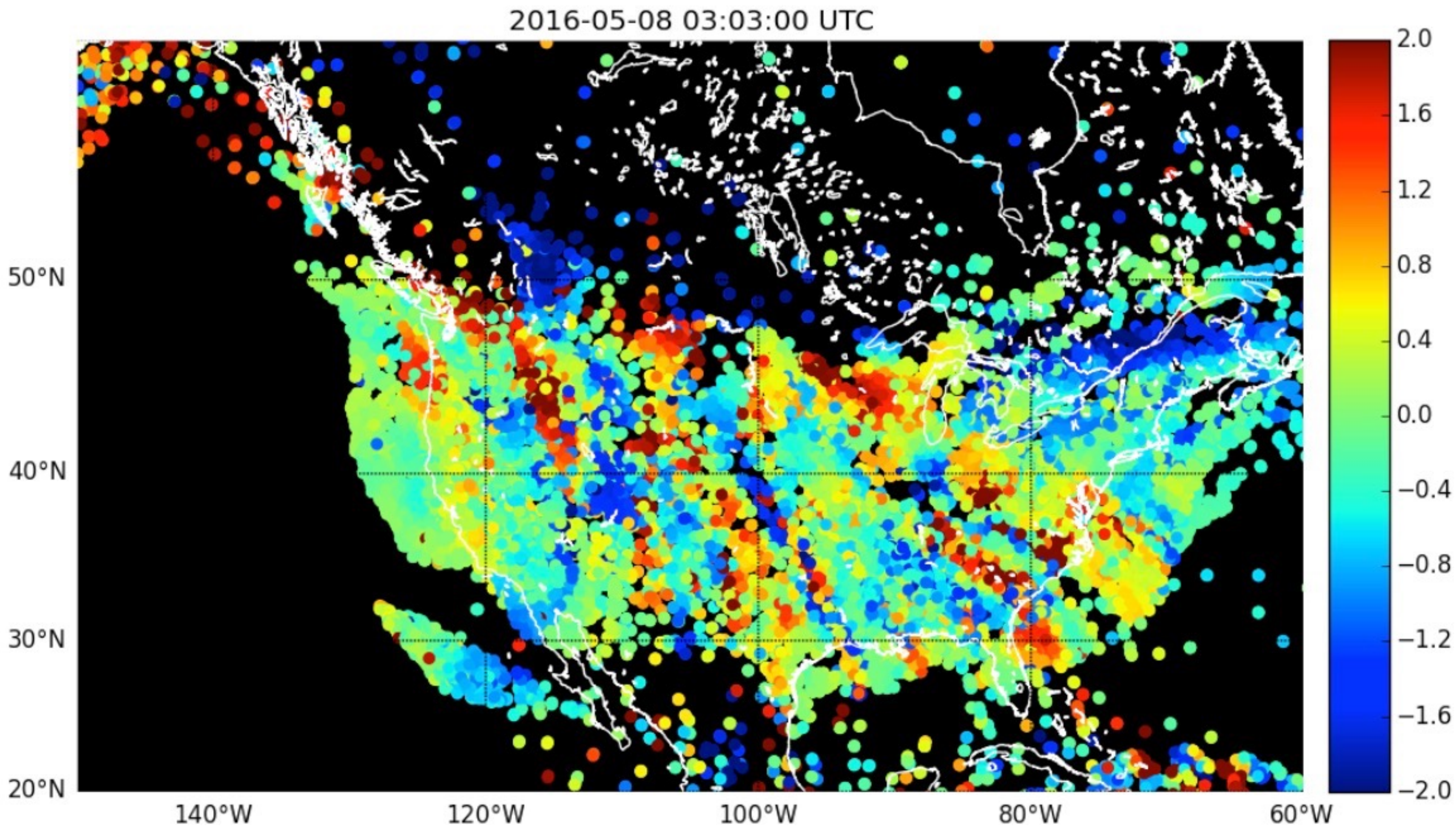

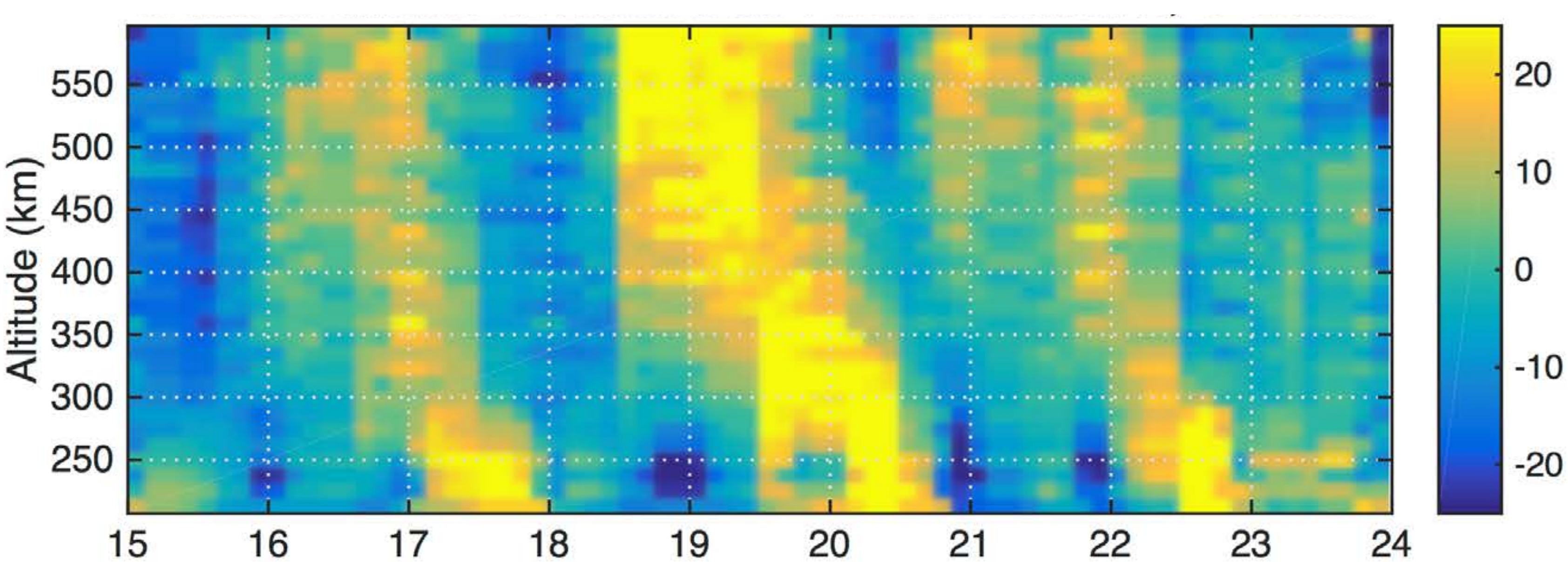

Viewing traveling ionospheric disturbances (TIDs) in 3-D

Examples of LSTIDs propagating horizontally (GPS total electron content in TECu; top) and vertically (Millstone Hill incoherent scatter radar electron density in %; bottom)

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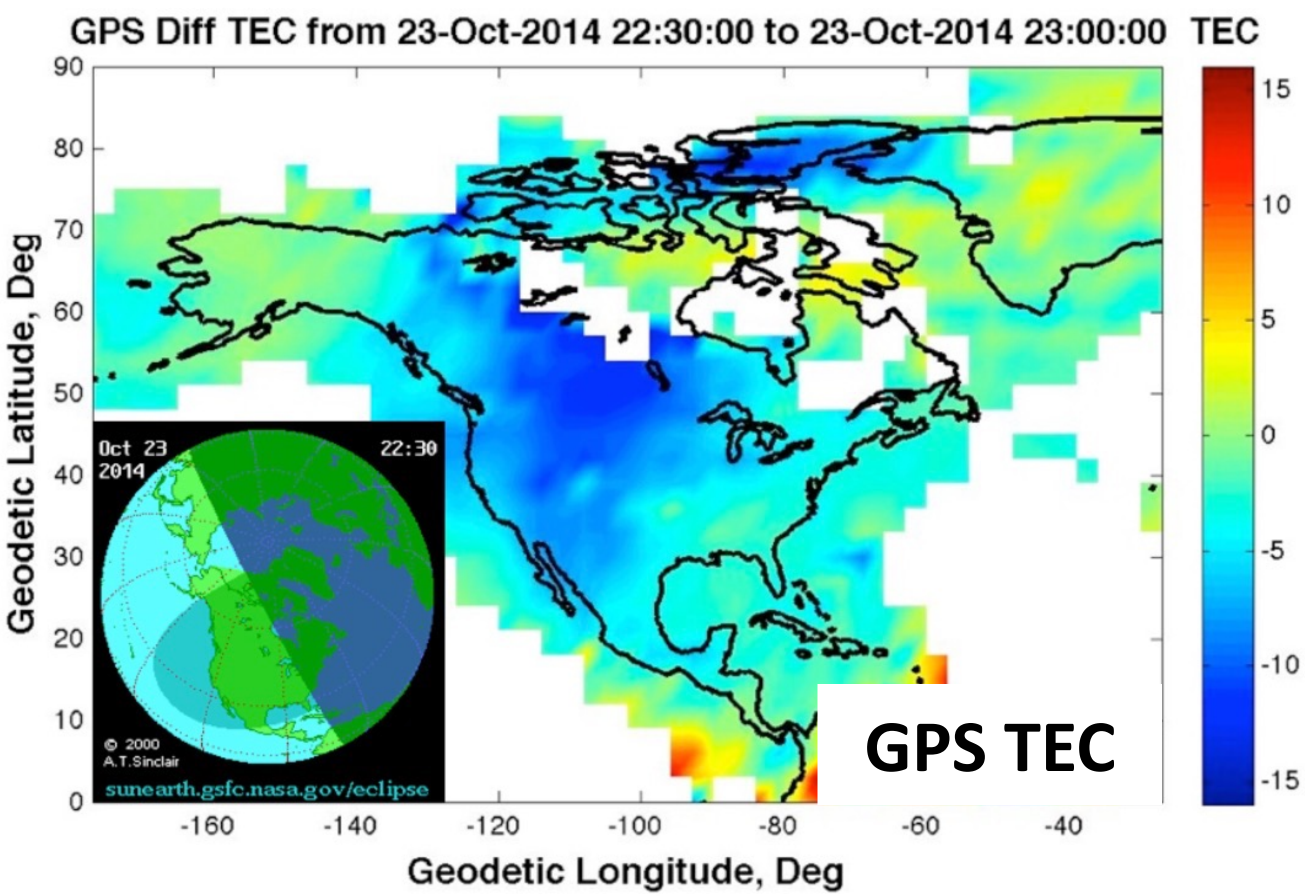
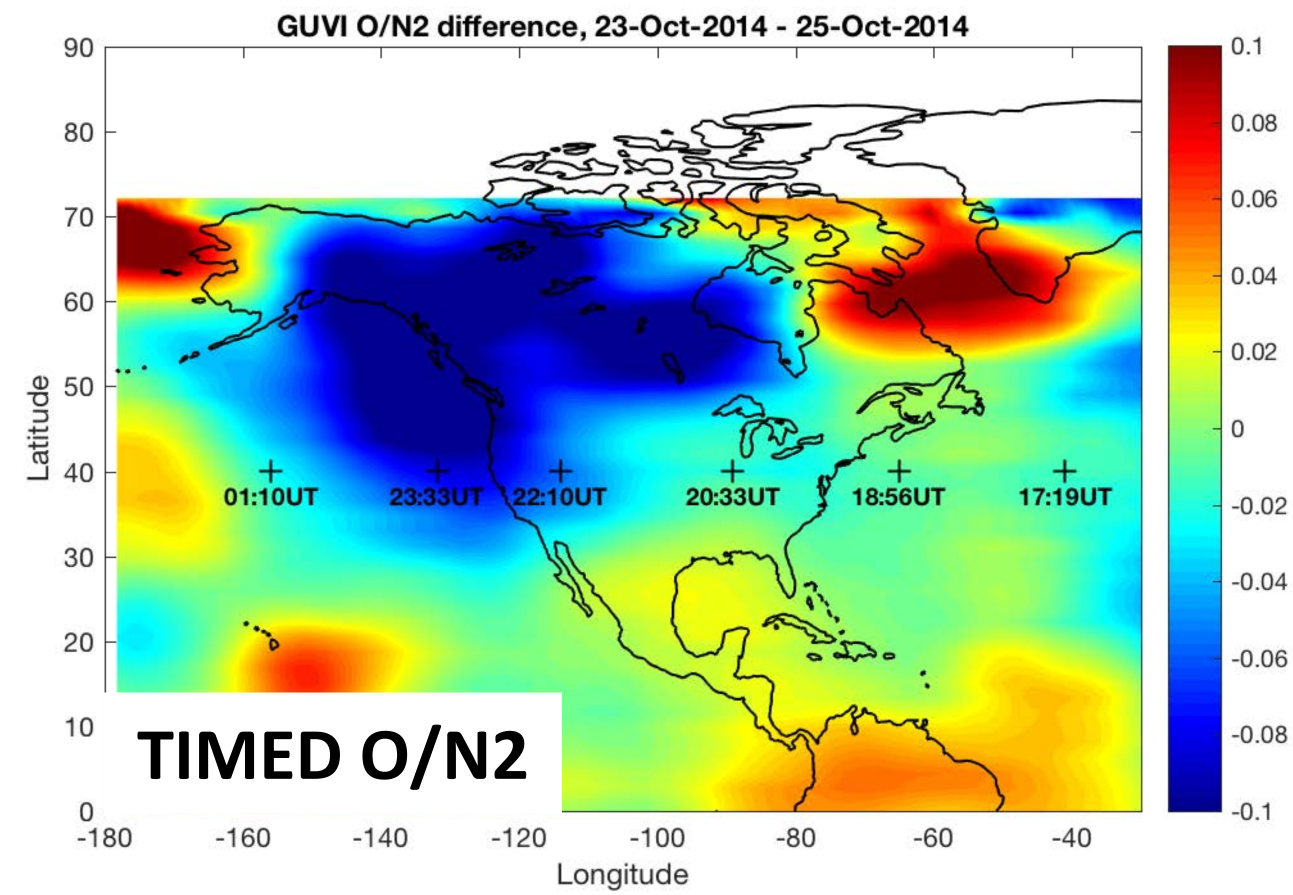




Ionospheric and Thermospheric Science from Eclipse Observations:

- Solar Eclipse-excited Traveling Ionospheric Disturbances and Atmospheric Gravity Waves (GNSS, ISR)
- High Accurate Temporal and Altitudinal Variation of the Whole Ionosphere over Partially Eclipsed Zones (Incoherent scatter radars)
- Temporal and Latitudinal Variation of the Ionosphere and Thermosphere Due to the Eclipse (GNSS, TIMED, DMSP)

University of Colorado Boulder

CEDAR Workshop
June 19-23, 2017
Keystone, CO

Studying the D-region ionosphere response to the total solar eclipse through data and modeling

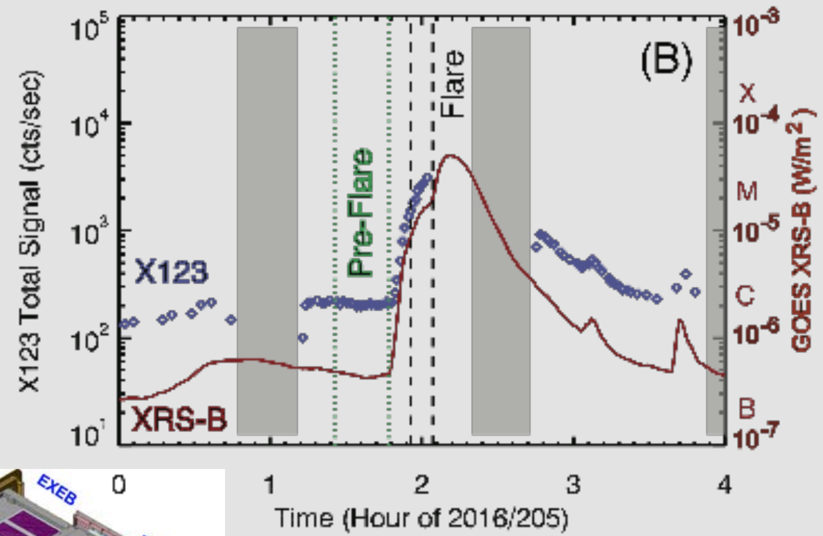
Robert A. Marshall[1]

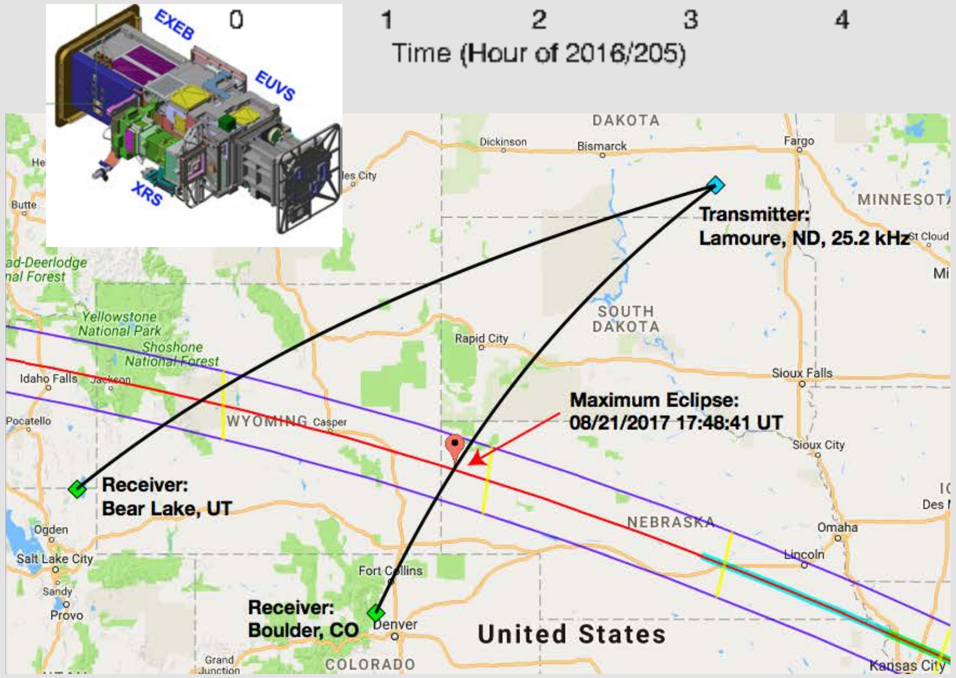
1. Aerospace Engineering Sciences, University of Colorado Boulder, Boulder, CO

D-region response to Total Solar Eclipse

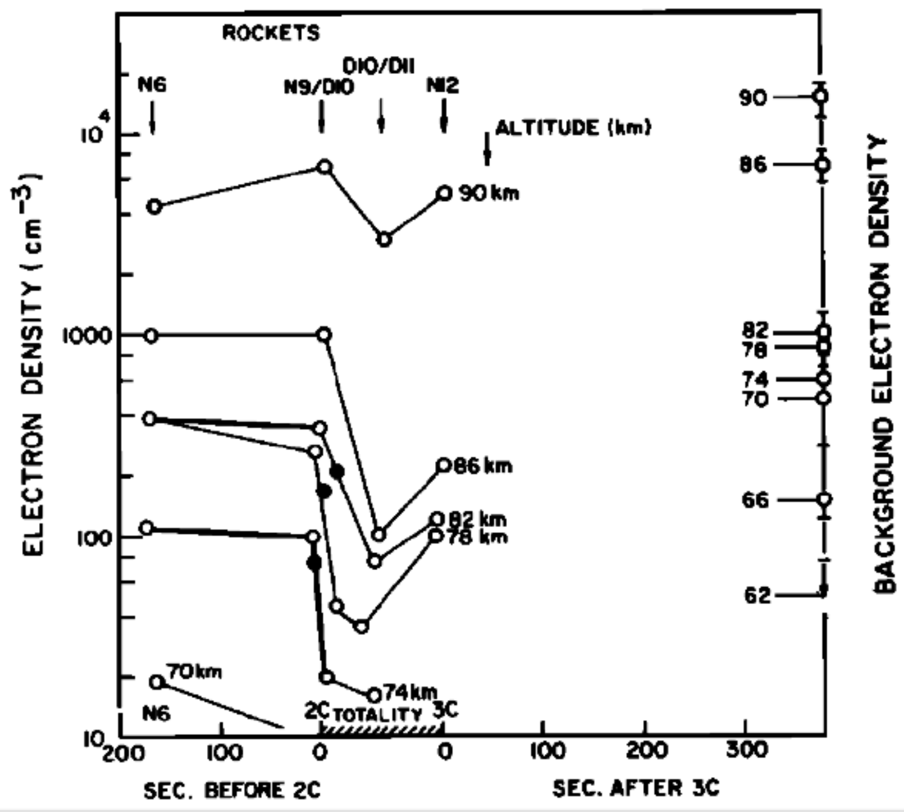
- **Eclipse 2017 provides a unique opportunity to study the D-region when the sun is "turned off"**
- **SQ: What are the contributions of solar Lyman-alpha, EUV, soft X-rays, and hard X-rays to the production of D-region ionization?**

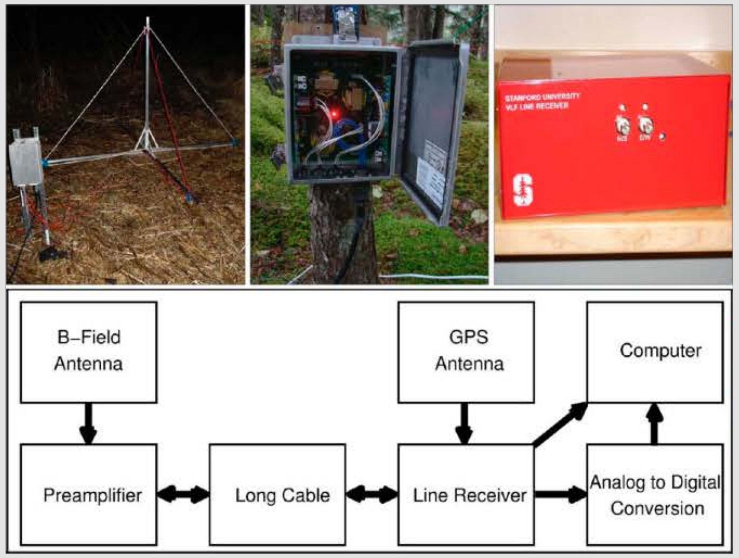
We use a combination of spacecraft ionizing radiation data, subionospheric VLF measurements, and chemistry and propagation modeling to quantify the effects of the eclipse on the D-region ionosphere.

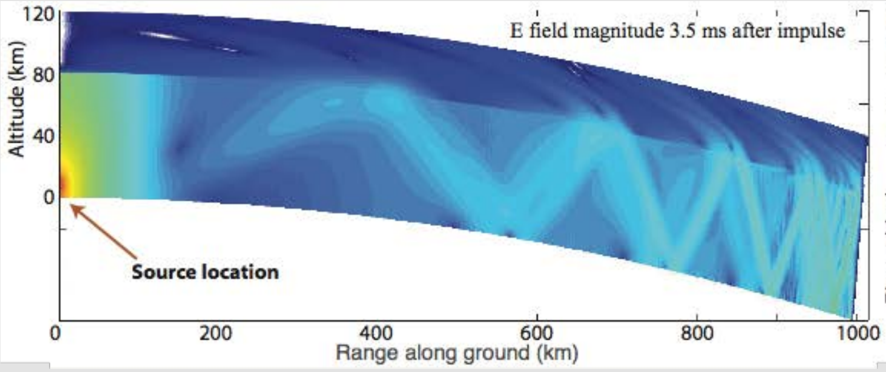


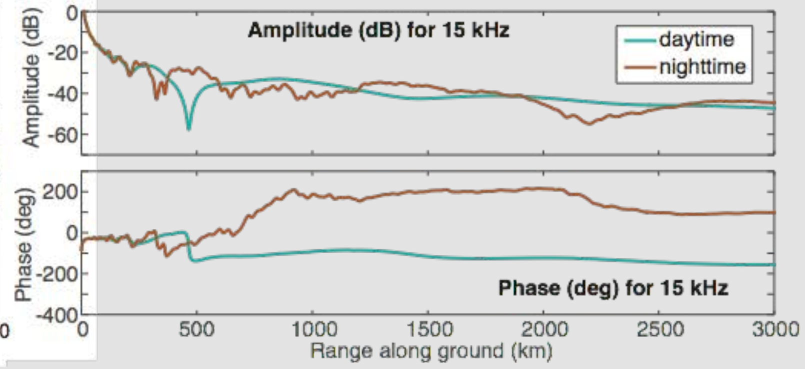


Previous study (Sears, 1981) used rocket experiments to measure electron density









HamSCI: The Ham Radio Science Citizen Investigation

N. A. Frissell[1], J. Katz[1], J. Vega[1], S. Gunning[1], A.J. Gerrard[1], M.L. Moses[2], G.D. Earle[2], R.W. McGwier[2], E.S. Miller[3], S.R. Kaeppler[4], G. Perry[5], P.J. Erickson[6], J. Dzekevich[7], H.W. Silver[8], and the RBN Team

[1]NJIT, [2]Virginia Tech, [3]JHU/APL, [4]SRI Int., [5]Univ. Of Calgary, [6]MIT Haystack, [7]HamSCI Community, [5]ARRL

HamSCI
http://hamsci.org

nathaniel.a.frissell@njit.edu

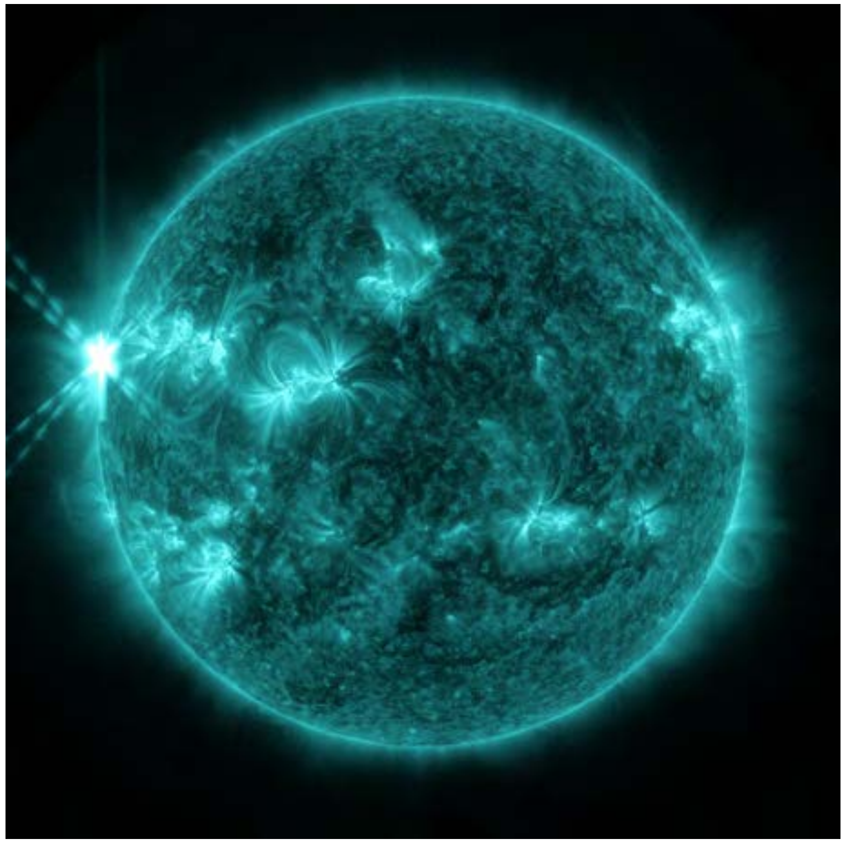
Amateur Radio and the HF Bands

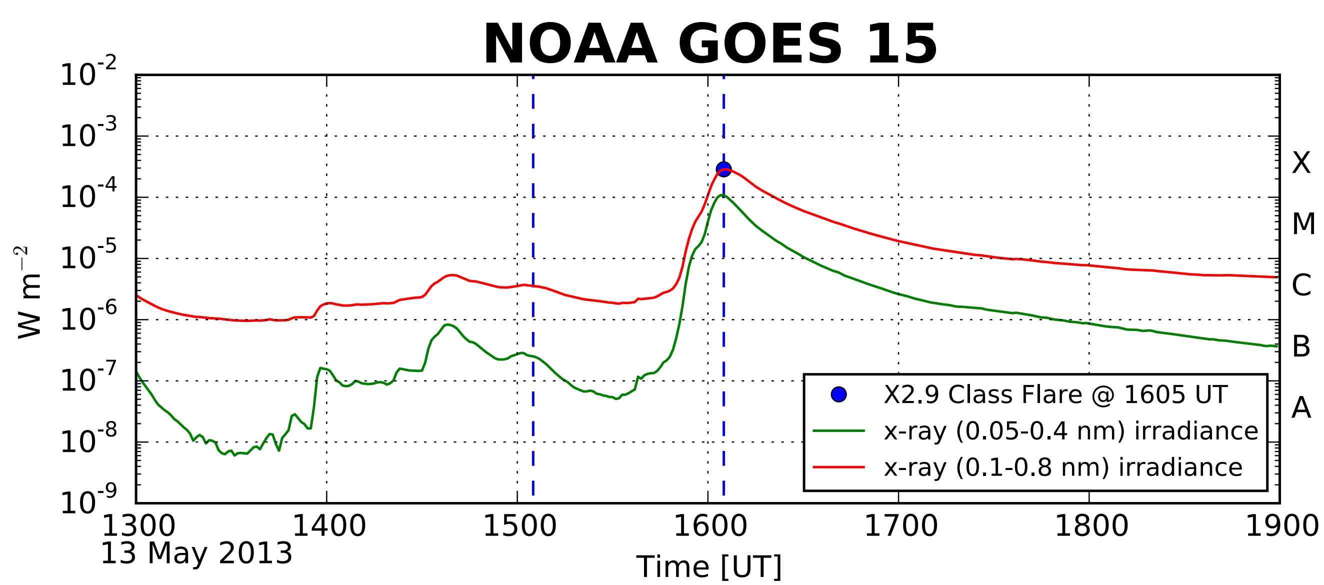
Frequency	Wavelength
1.8 MHz	160 m
3.5 MHz	80 m
7 MHz	40 m
10 MHz	30 m
14 MHz	20 m
18 MHz	17 m
21 MHz	15 m
24 MHz	12 m
28 MHz	10 m
50 MHz	6 m

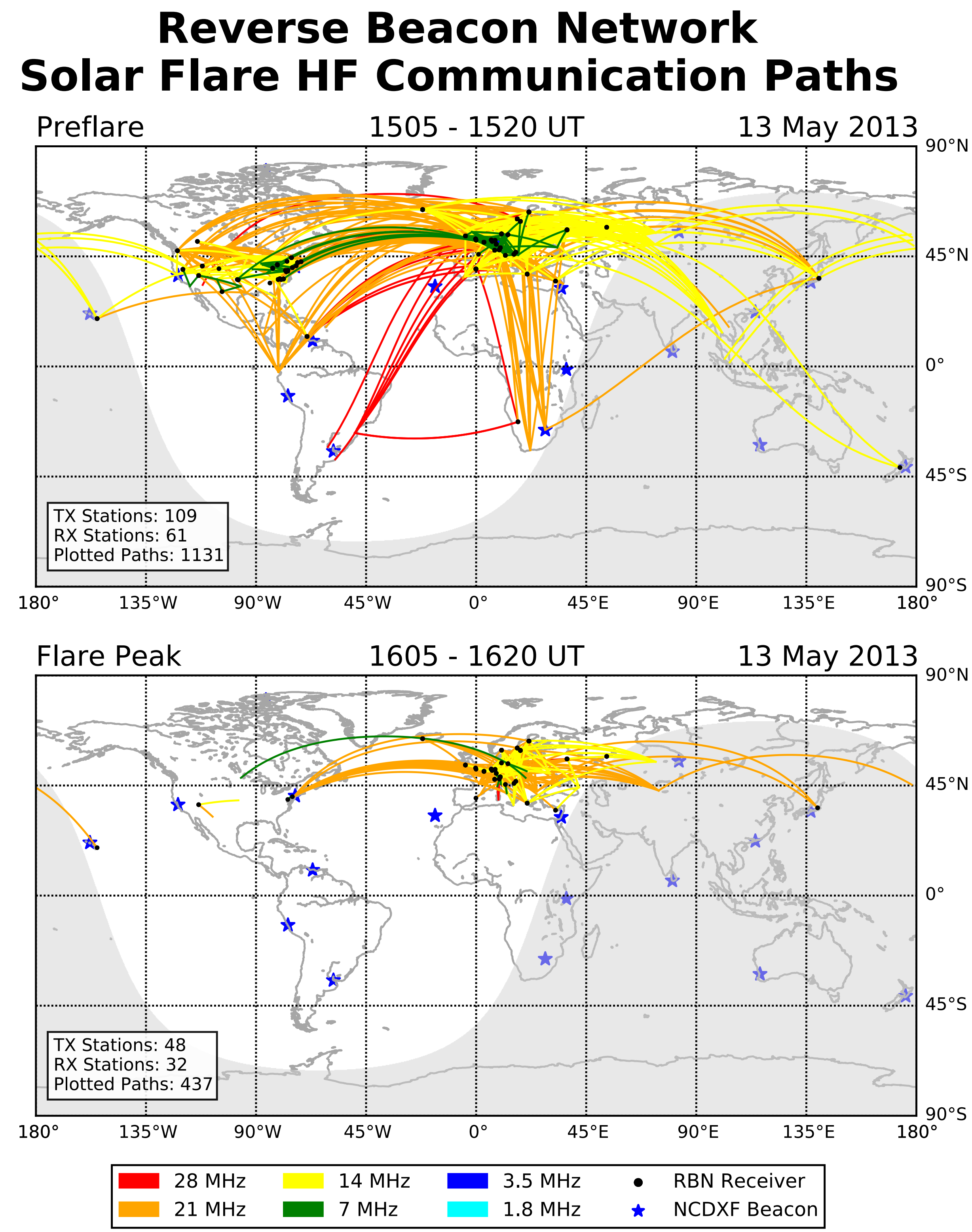
K2MFF, The NJIT Ham Radio Station

- Hobbyists routinely use HF-VHF transionospheric links.
- Often ~100 W into dipole antennas.

RBN & A Solar Flare

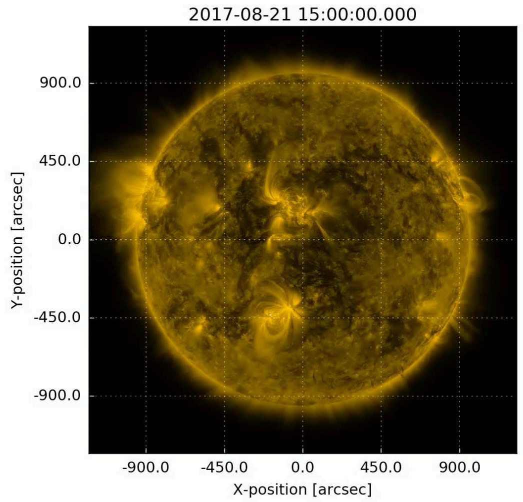

[NASA SDO]

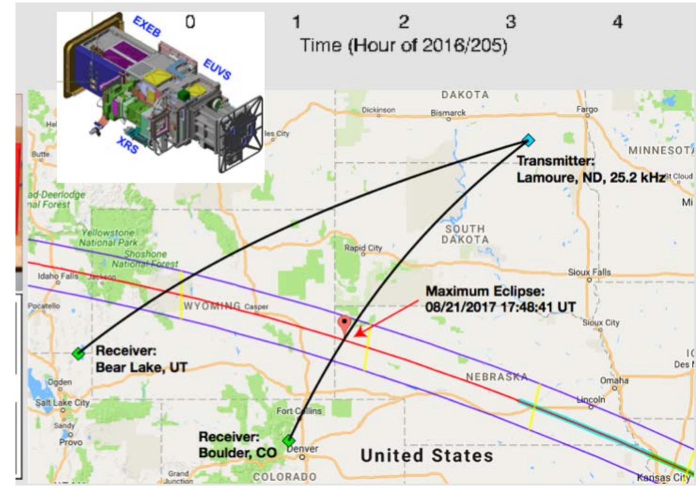


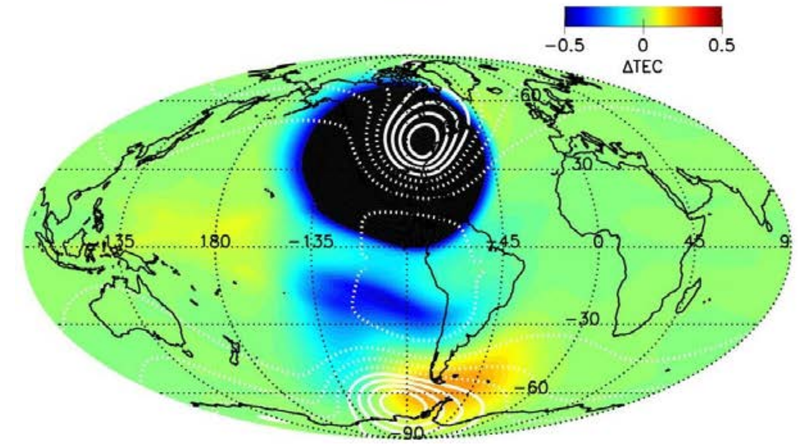


[*Frissell et al.*, 2014, *Space Weather*]

Summary







- The 2017 Eclipse will feature the most comprehensive observation and modeling efforts to date
- Detailed D, E, F region investigations, both modeling and observations
- New observational approaches (e.g. Citizen science)
- Excellent example of CEDAR system science approaches
- We stand to learn a great deal about the coupled geospace system

To find out more at this meeting:

- Friday AM: 2017 Eclipse session (S. Zhang; Torreys 1 and 2)
- Thursday CEDAR Banquet: HamSCI Citizen Science (N. Frissell)

Thanks for your attention!

MIT HAYSTACK OBSERVATORY

NASA

NSF