

# The Great American Solar Eclipse of August 21, 2017: Science Questions and Observations

A. J. Coster, L. Goncharenko, S. Zhang, P. J. Erickson, J. Soohoo,  
E. Derome, J. Swoboda, G. Earle, L. Kordella, D. J. Knipp, and T. Bullet

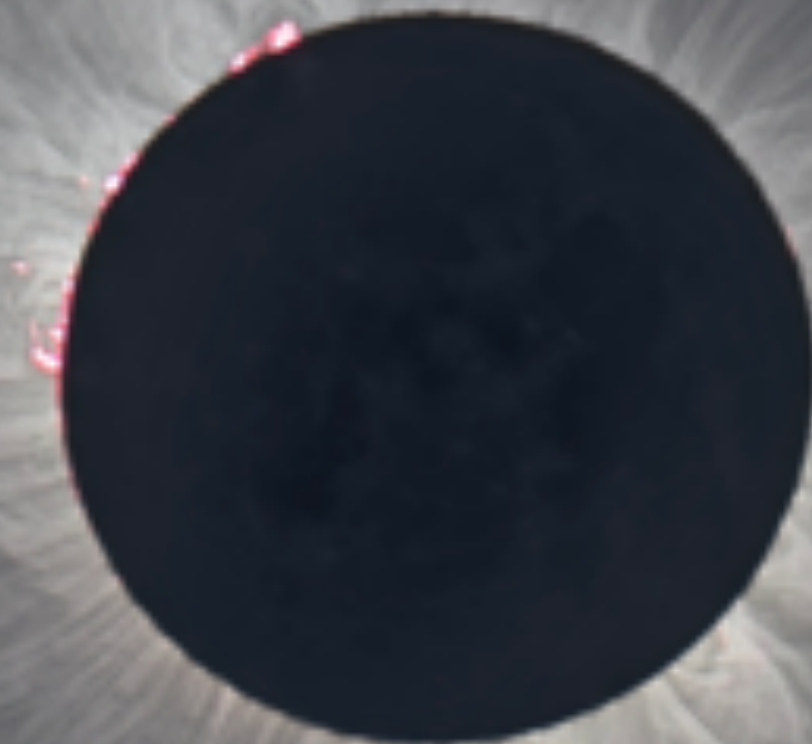
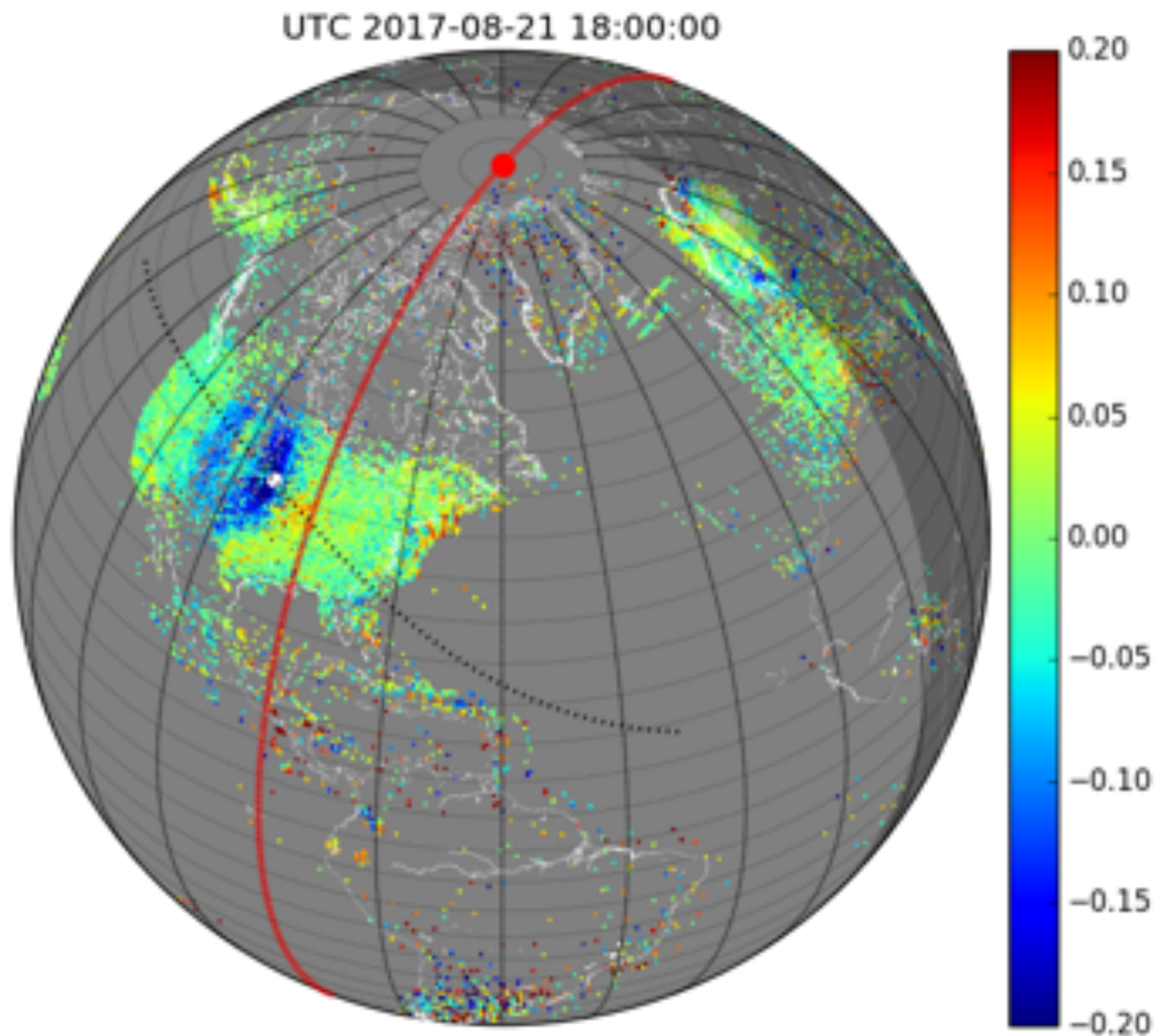


Image Courtesy of NASA



Differential TEC using Savitzky-Golay filter with a 2 hour sliding window and a linear basis function.

A 2 hr window was used because the eclipse (partial or totality) lasted about 2 hrs at each given location

Red line is noon meridian  
White dot: totality location and approximate width





# GNSS Campaign Overview for Aug 21<sup>st</sup> Solar Eclipse

5 GNSS receivers borrowed from UNAVCO, 2 borrowed from MIT

- Tom Clark (NEROC) – SC
  - Greg Earle (VT) – SC
  - Magda Moses (VT ) – KS
  - John Hubbard (NRL) – MO
- Delores Knipp (U. Colorado) – MO
- John Swoboda (MIT) & Terry Bullett (NOAA) – WY
  - Lee Kordella (VT) – OR
- GPS data transferred back to Haystack in near real-time
  - All hardware deployed from Haystack Observatory
    - Borrowed hardware returns to UNAVCO directly
  - Remaining hardware returns to Haystack Observatory



Eclipse 2017

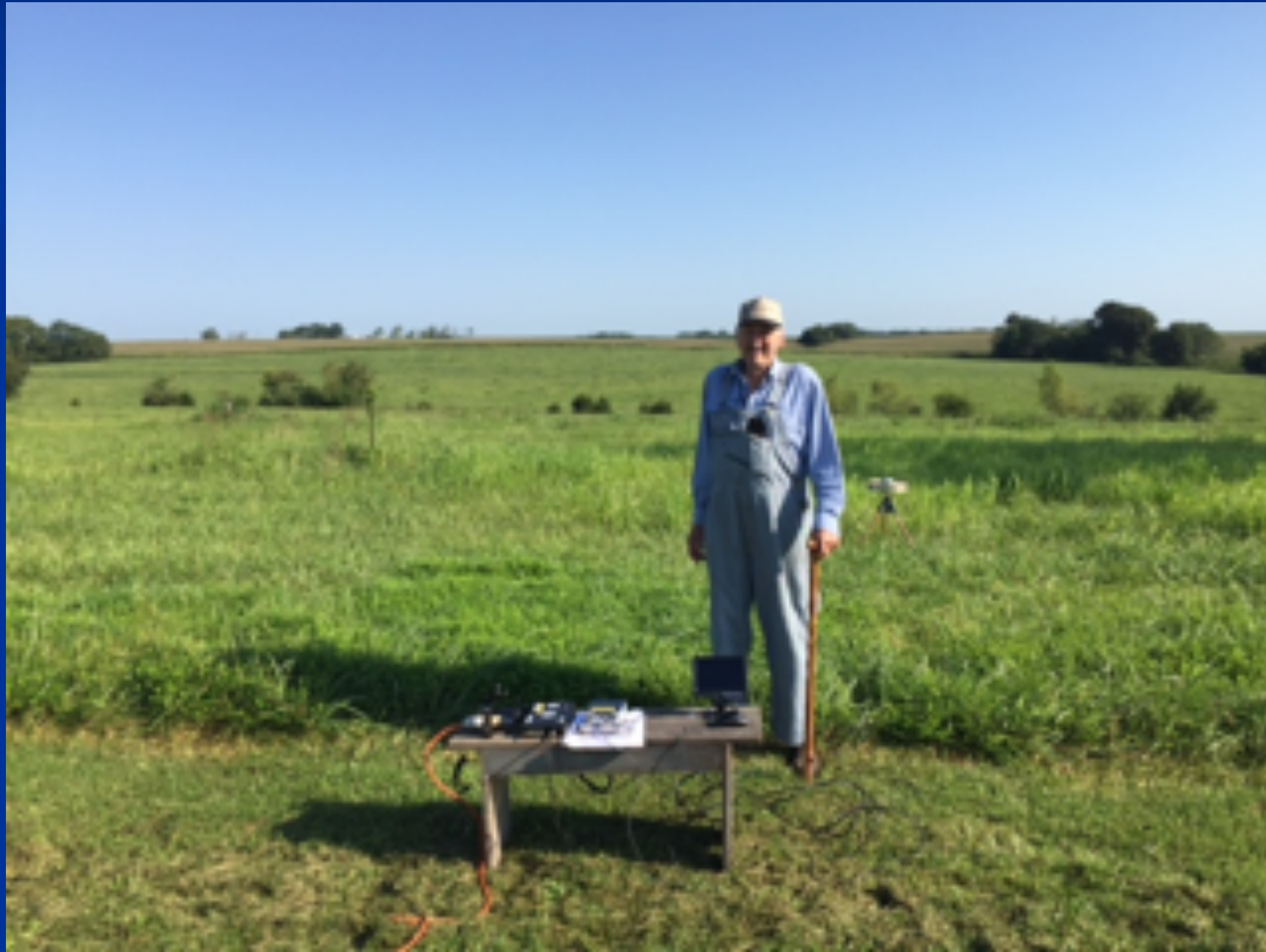


# UNAVCO RECEIVER SETUP

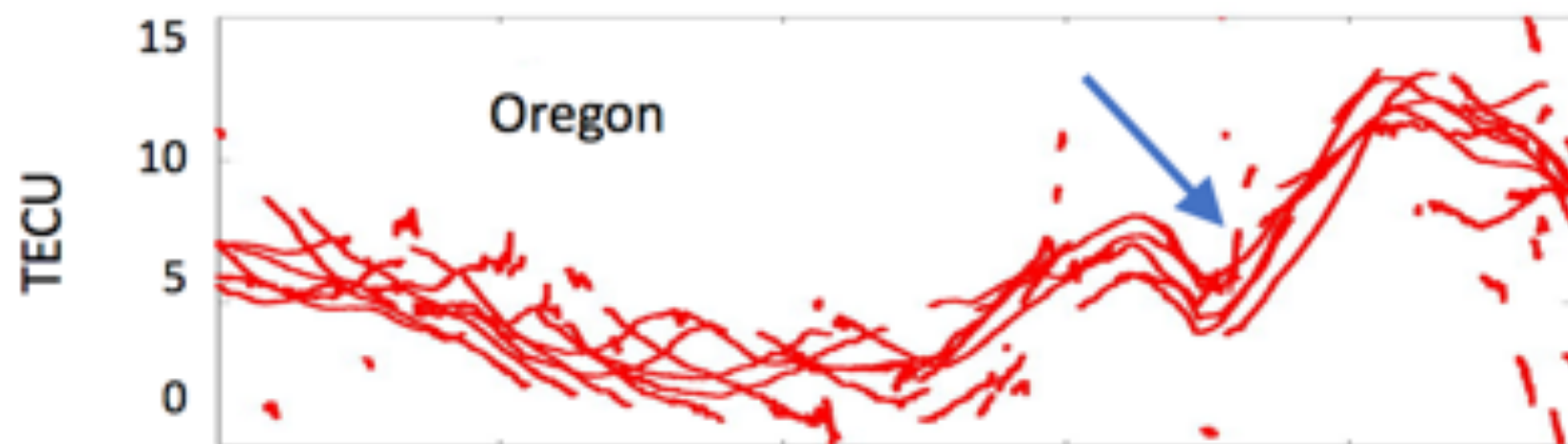
Courtesy Delores Knipp



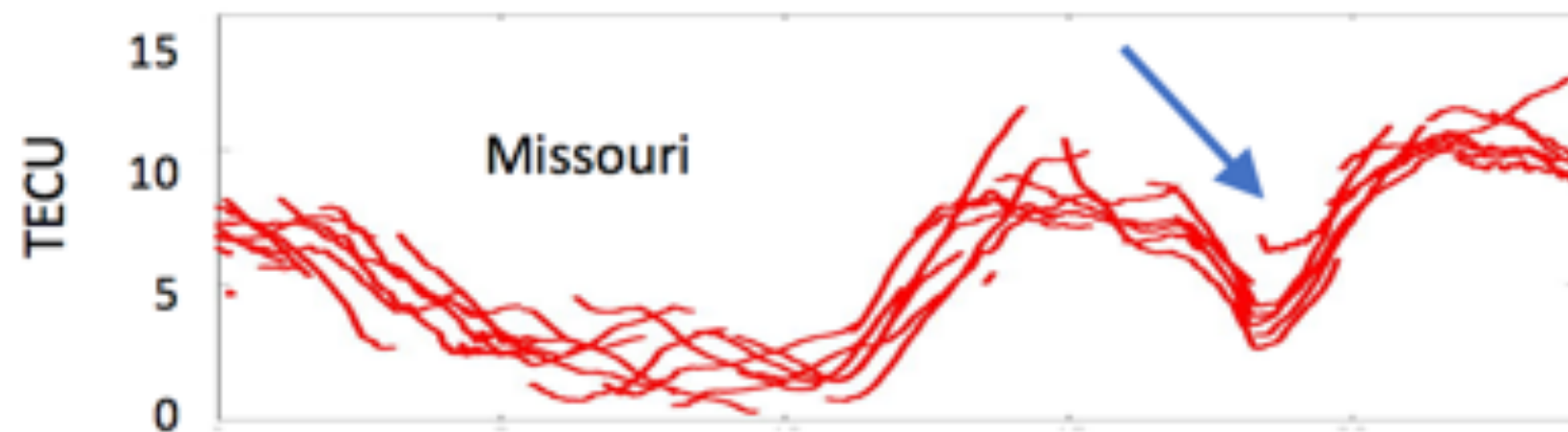
# Delores Knipp's 90 year old father



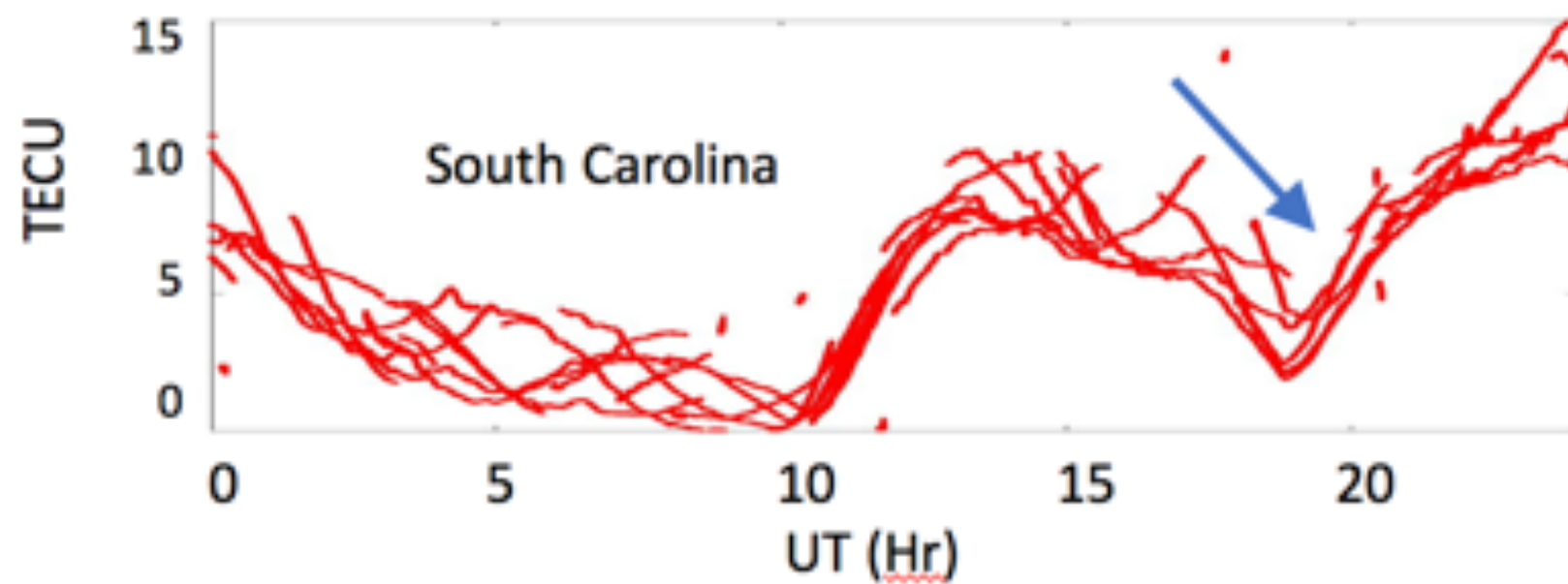
Courtesy Delores Knipp



10:15 am

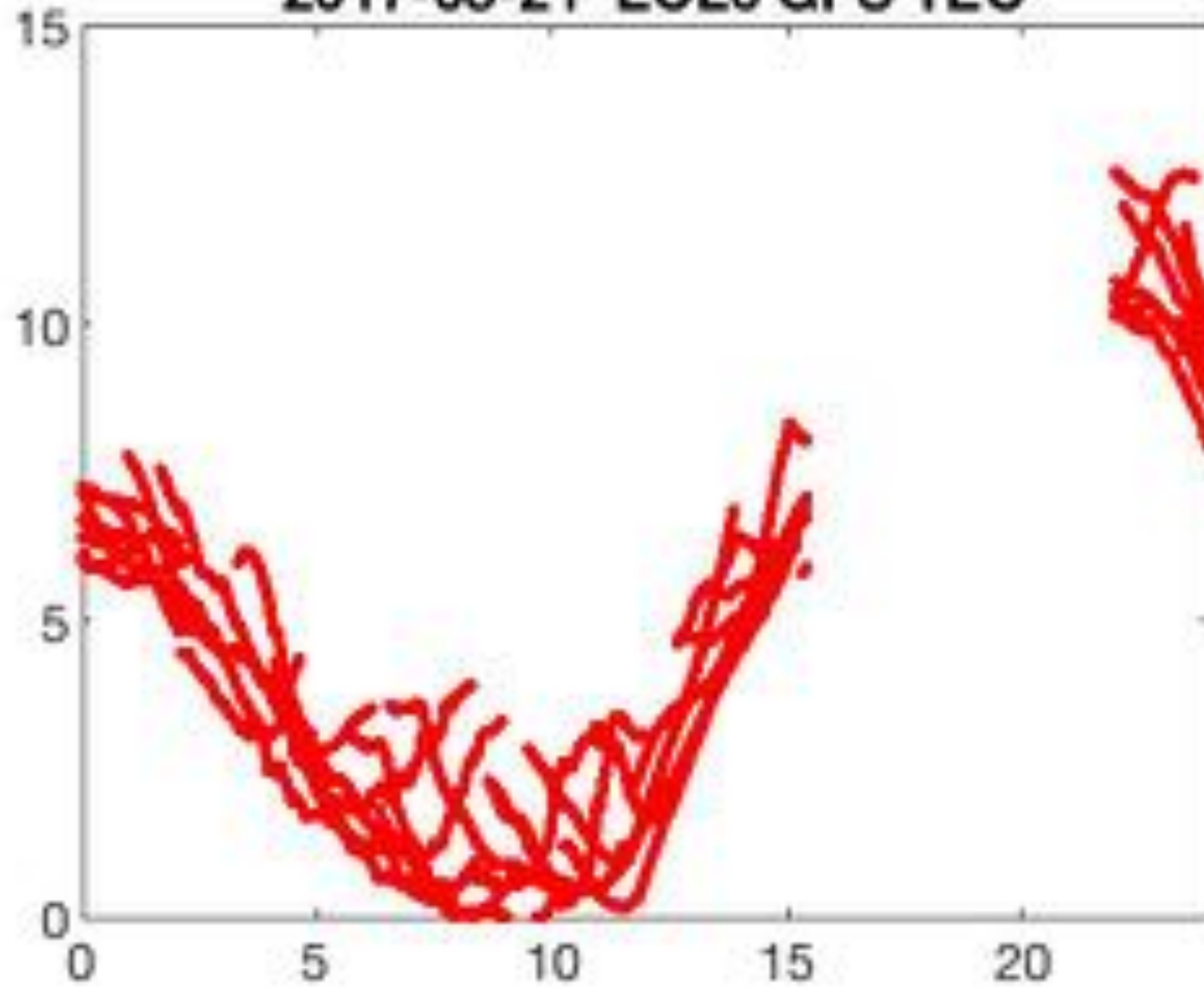


1:14 pm



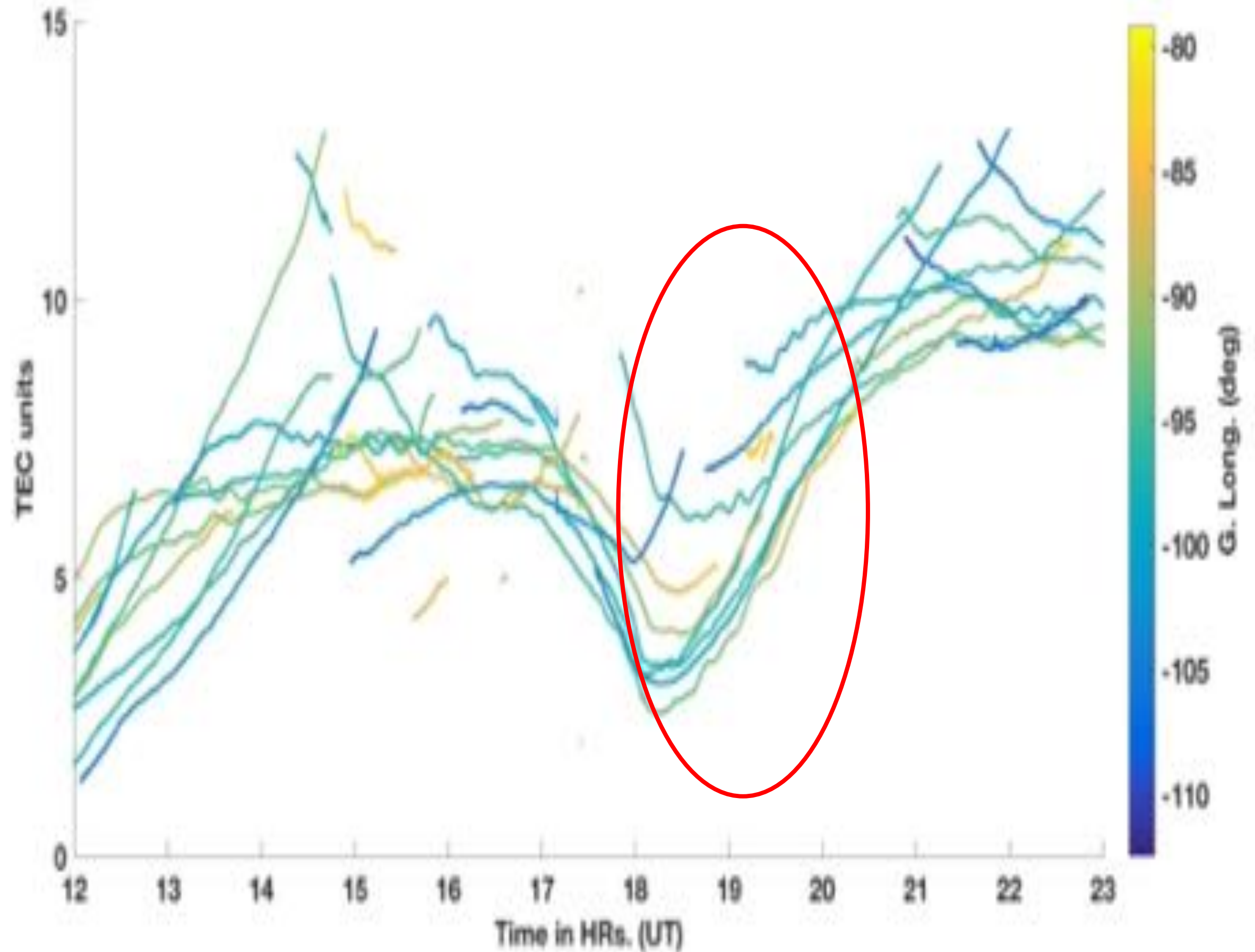
2:43 pm

2017-08-21 ECL6 GPS TEC

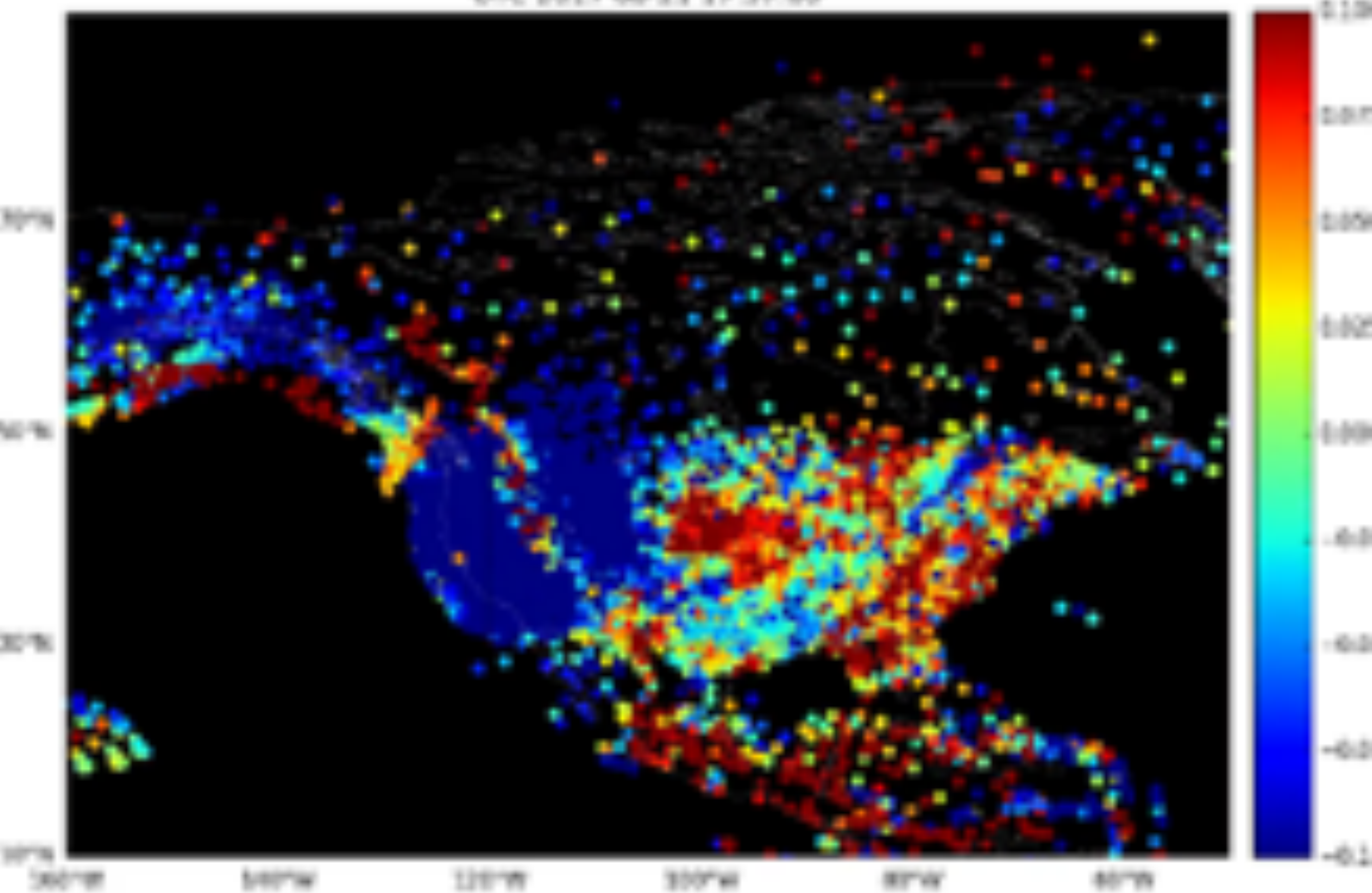




2017-Aug-21 ECL5 from ecl5 Lat. > 30.535215 & 40.804278 deg.



UTC 2017-08-21 17:37:00



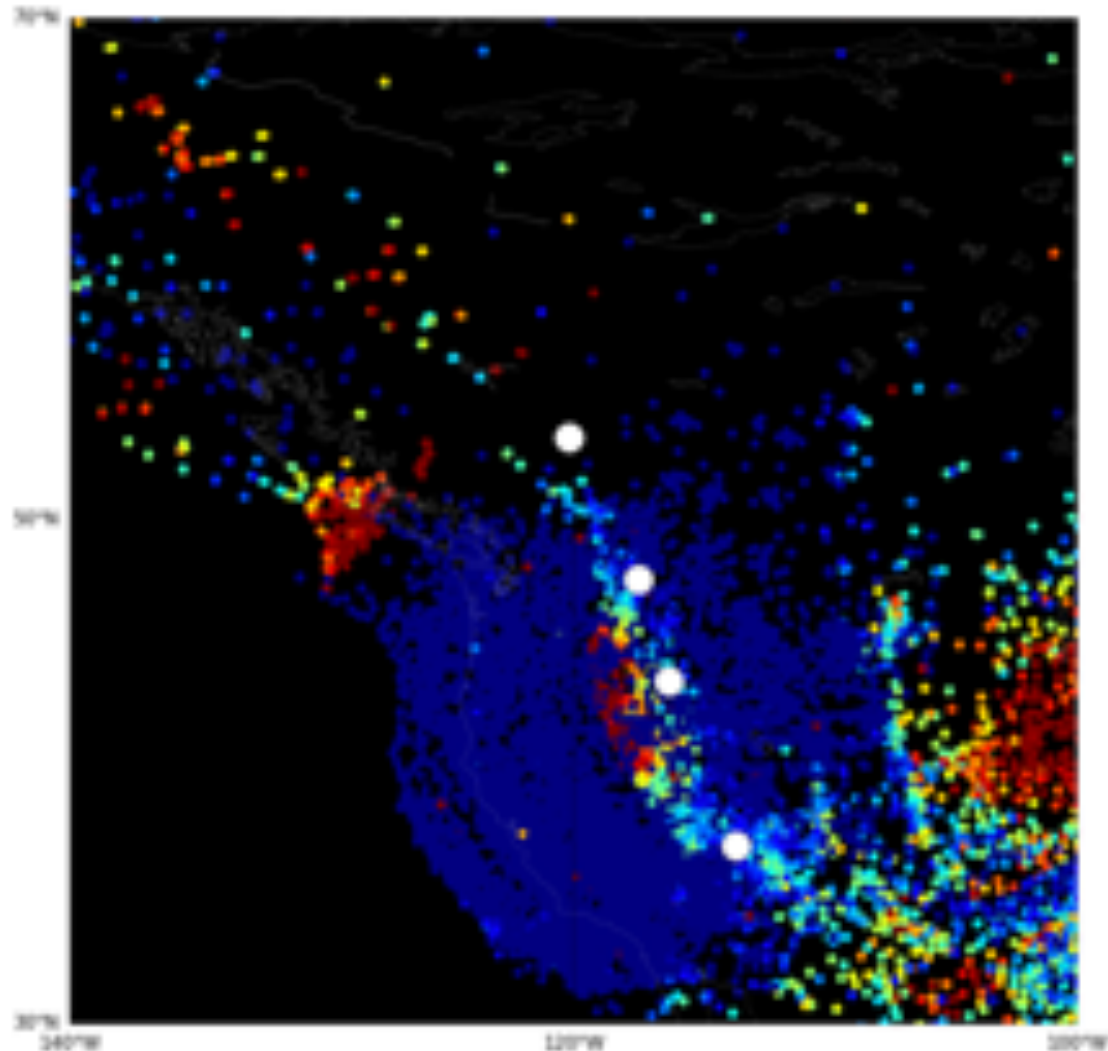




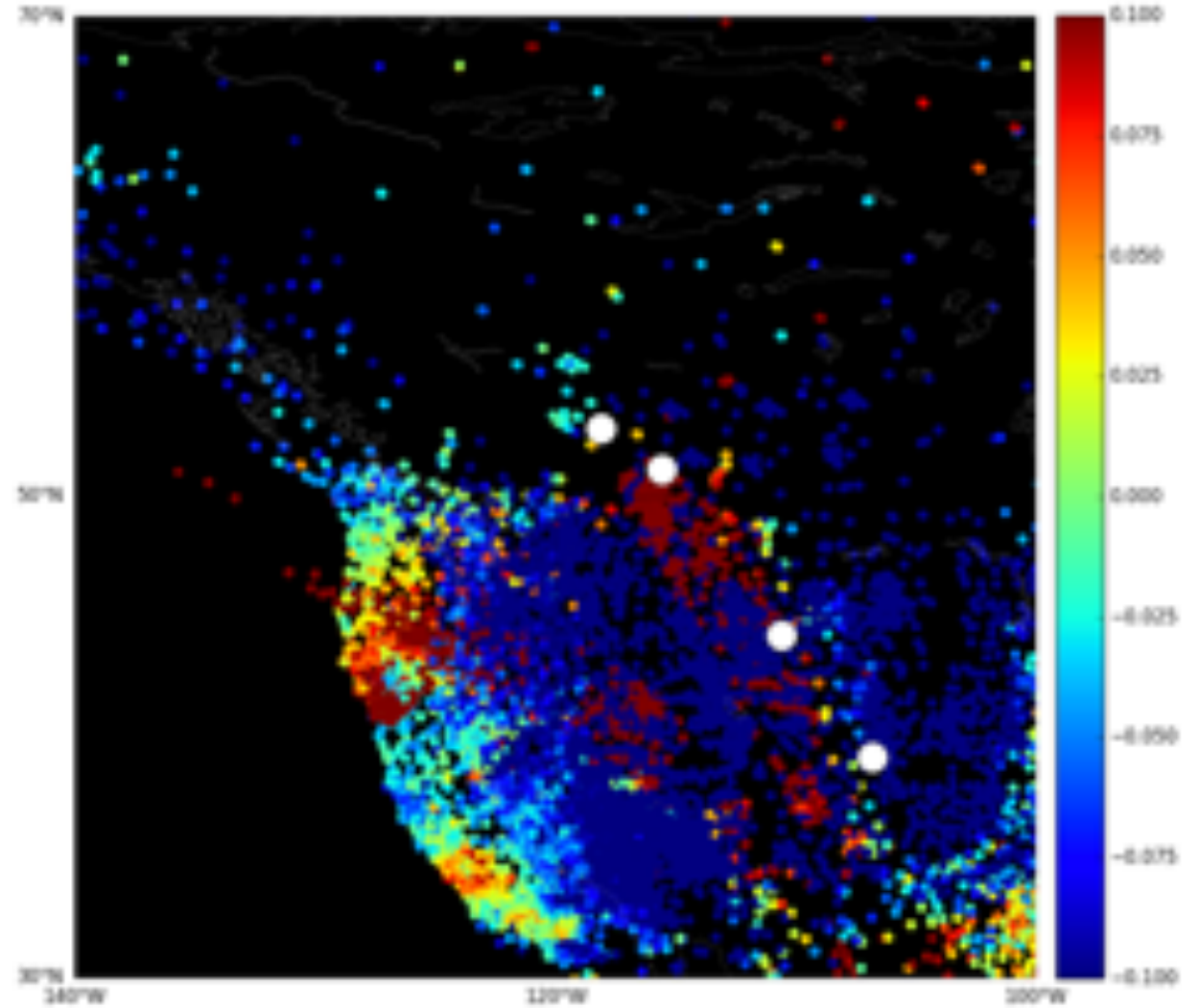


# Evidence of enhanced TIDs on the western side and eastern side of the Rocky Mountain range.

**Eclipse Max at Boise, ID at 17:27**  
**17:32:00 UTC**



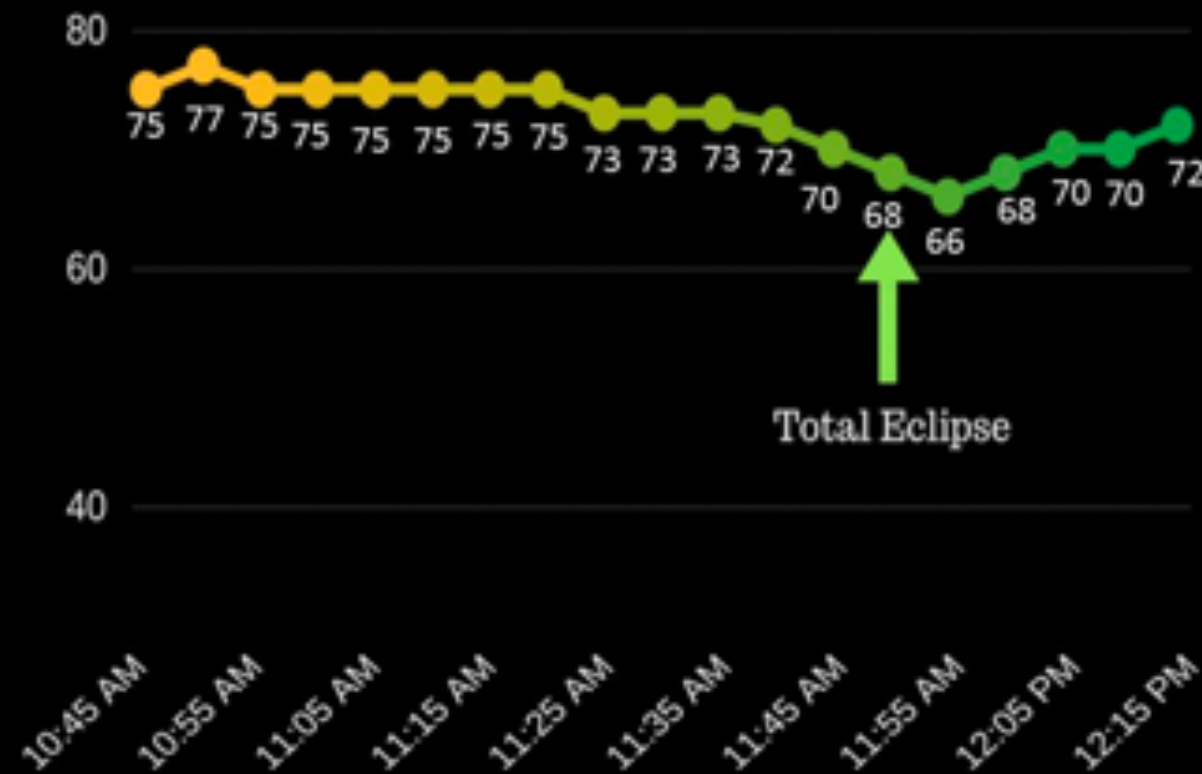
**Eclipse Max at Jackson, WY ID at 17:35**  
**17:48:00 UTC**



In the left hand plot, the white dots represent: McBride, CA, Spokane, WA, Boise, ID, and St. George, UT  
and  
in the right hand plot, the white dots represent,: Banff, CA, Jasper, MT, Jackson, WY, and Aspen, CO

# Douglas, WY Eclipse Temperature Drop

11 Degree Drop



Published on: 08/21/2017 at 1:10PM



**NWS Cheyenne**   
@NWSCheyenne

Follow

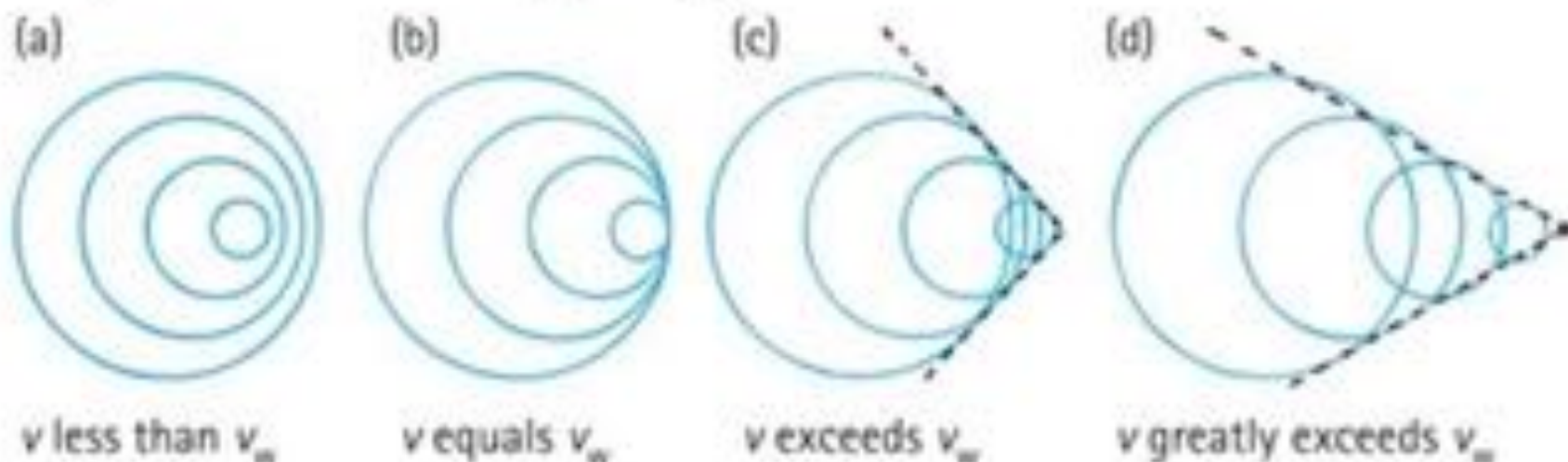
You may have noticed a chill in the air as the eclipse passed by. Douglas, WY dropped 11 degrees! [#SolarEclipse2017](#) [#wywx](#)

3:10 PM - Aug 21, 2017

1 35 55

# Bow Waves

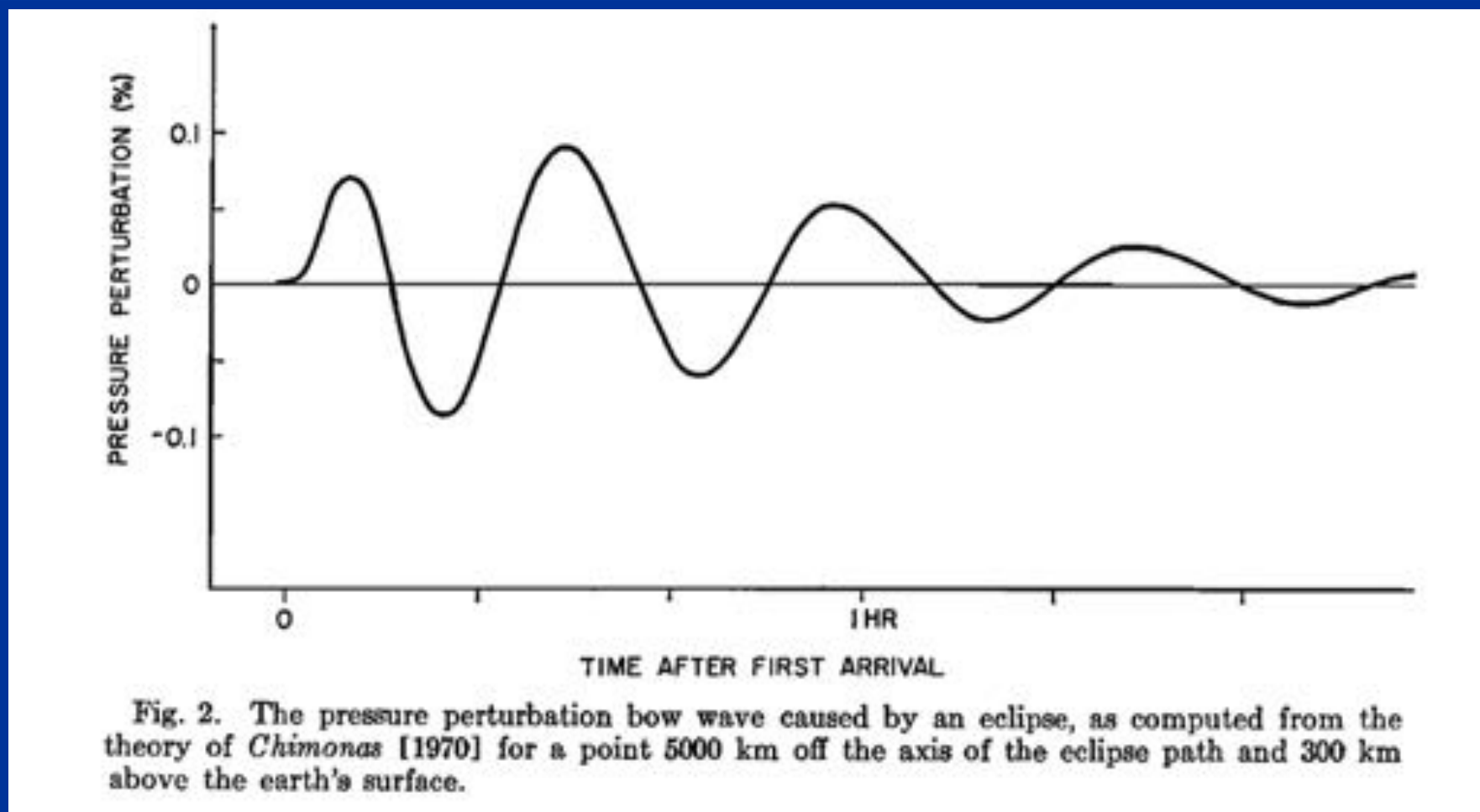
- Supersonic
  - Aircraft flying faster than the speed of sound.
- Bow wave
  - V-shape form of overlapping waves when object travels faster than wave speed.
  - An increase in speed will produce a narrower V-shape of overlapping waves.





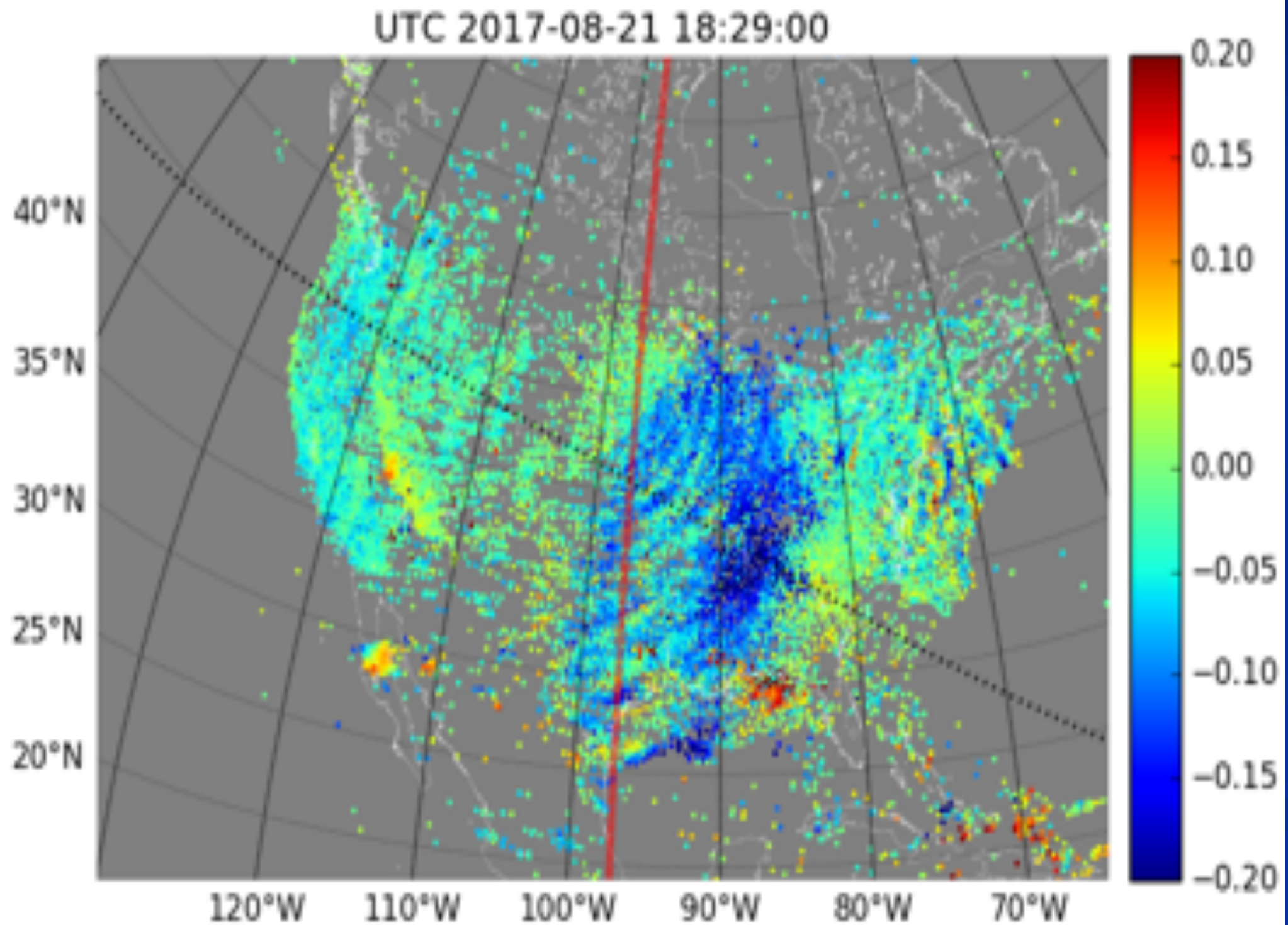
# Bow Wave Theories

- Chimonas (1970)
- Fritts and Luo (1993)
- Eckermann (2007) – NOGAS-Alpha



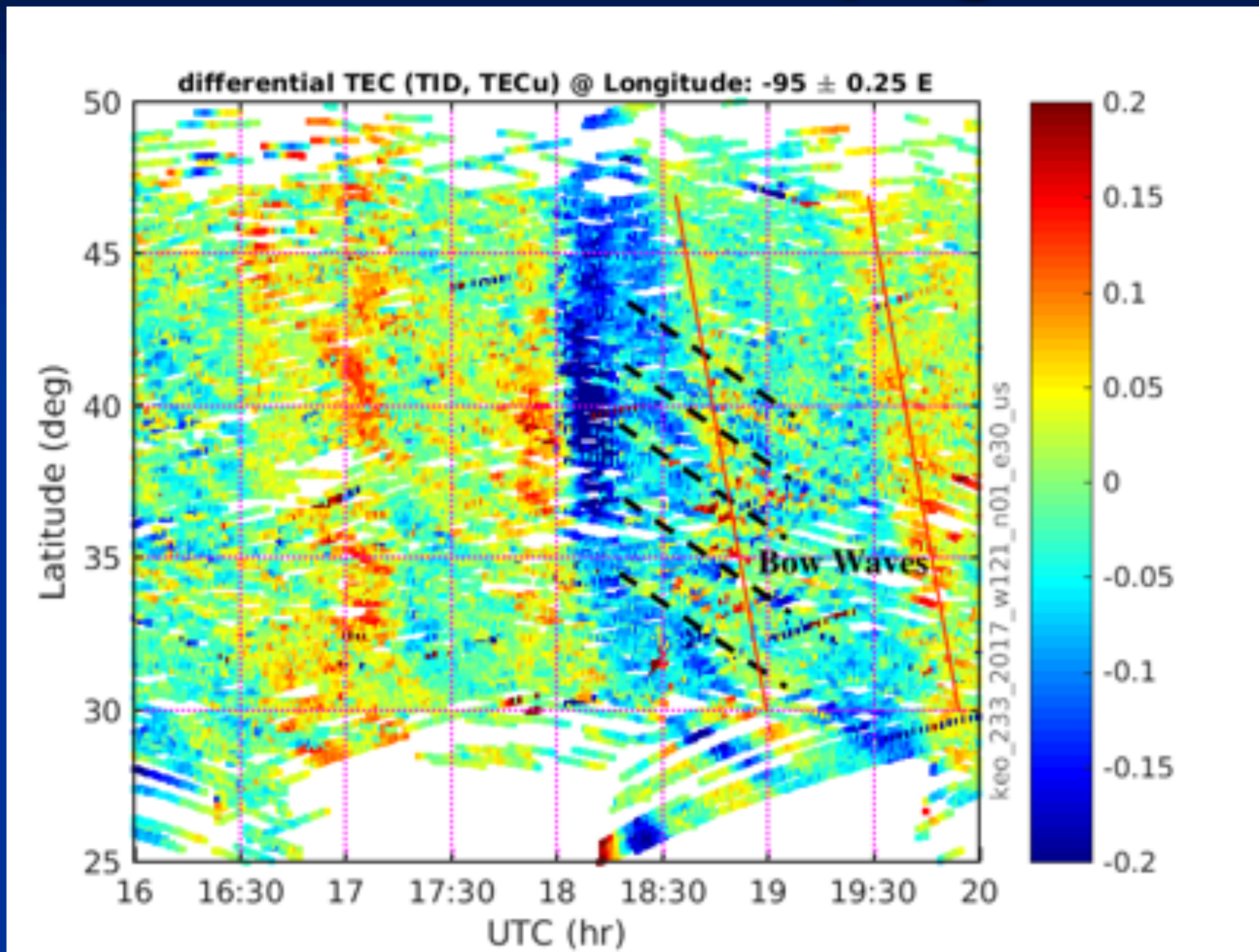
# Bow Waves

$W=121$ ,  
 $n=1$





# Meridional Propagation



Bow waves:  
(2.5 deg/0.5 hr)  
140m/s  
in meridional  
direction

This finding was recently reported by multiple press sources, including Newsweek.  
Best quote:

'Bow Waves' detected after solar eclipse of August 2017, scientists still clueless



# Some of the papers published

Research Letter

## **SAMI3 prediction of the impact of the 21 August 2017 total solar eclipse on the ionosphere/plasmasphere system**

J. D. Huba , D. Drob

Geophysical Research Letters | Volume 44, Issue 12

First published: 12 June 2017

## **GNSS Observations of Ionospheric Variations During the 21 August 2017 Solar Eclipse**

Anthea J. Coster, Larisa Goncharenko, Shun-Rong Zhang, Philip J. Erickson, William Rideout, Juha Vierinen

Geophysical Research Letters | First Published: 20 November 2017

## **Ionospheric Bow Waves and Perturbations Induced by the 21 August 2017 Solar Eclipse**

Shun-Rong Zhang, Philip J. Erickson, Larisa P. Goncharenko, Anthea J. Coster, William Rideout, Juha Vierinen

Geophysical Research Letters | First Published: 04 December 2017

## **Citation for: Ionospheric Response to the Solar Eclipse of 21 August 2017 in Millstone Hill (42N) Observations**

Larisa P. Goncharenko, Philip J. Erickson, Shun-Rong Zhang, Ivan Galkin, Anthea J. Coster, Olusegun F. Jonah

First published: 03 May 2018 | <https://doi.org/10.1029/2018GL077334>

## **Vertical and Oblique Ionosphere Sounding During the 21 August 2017 Solar Eclipse**

Terence Bullett , Justin Mabie

Geophysical Research Letters |

First published: 26 March 2018

## **Direct EUV/X-Ray Modulation of the Ionosphere During the August 2017 Total Solar Eclipse**

Sebastijan Mrak , Joshua Semeter, Douglas Drob, J. D. Huba

Geophysical Research Letters |

First published: 19 April 2018

## **Atmospheric Gravity Waves in the Ionosphere and Thermosphere During the 2017 Solar Eclipse**

Cissi Y. Lin, Yue Deng , Aaron Ridley

Geophysical Research Letters | Volume 45, Issue 11

First published: 19 April 2018

## **Ionospheric Bow Wave Induced by the Moon Shadow Ship Over the Continent of United States on 21 August 2017**

Yang-Yi Sun, Jann-Yenq Liu, Charles Chien-Hung Lin, Chi-Yen Lin, Ming-Hsueh Shen, Chieh-Hung Chen, Chia-Hung Chen, Min-Yang Chou

Geophysical Research Letters | First Published: 08 January 2018

## **Ionospheric Total Electron Content Response to the Great American Solar Eclipse of 21 August 2017**

Iurii Cherniak, Irina Zakharenkova

Geophysical Research Letters | First Published: 08 January 2018

## **The Lower Ionospheric VLF/LF Response to the 2017 Great American Solar Eclipse Observed Across the Continent**

M. B. Cohen , N. C. Gross, M. A. Higginson-Rollins, R. A. Marshall, M. Gołkowski, W. Liles, D. Rodriguez, J. Rockway

Geophysical Research Letters | Volume 45, Issue 8

First published: 25 March 2018



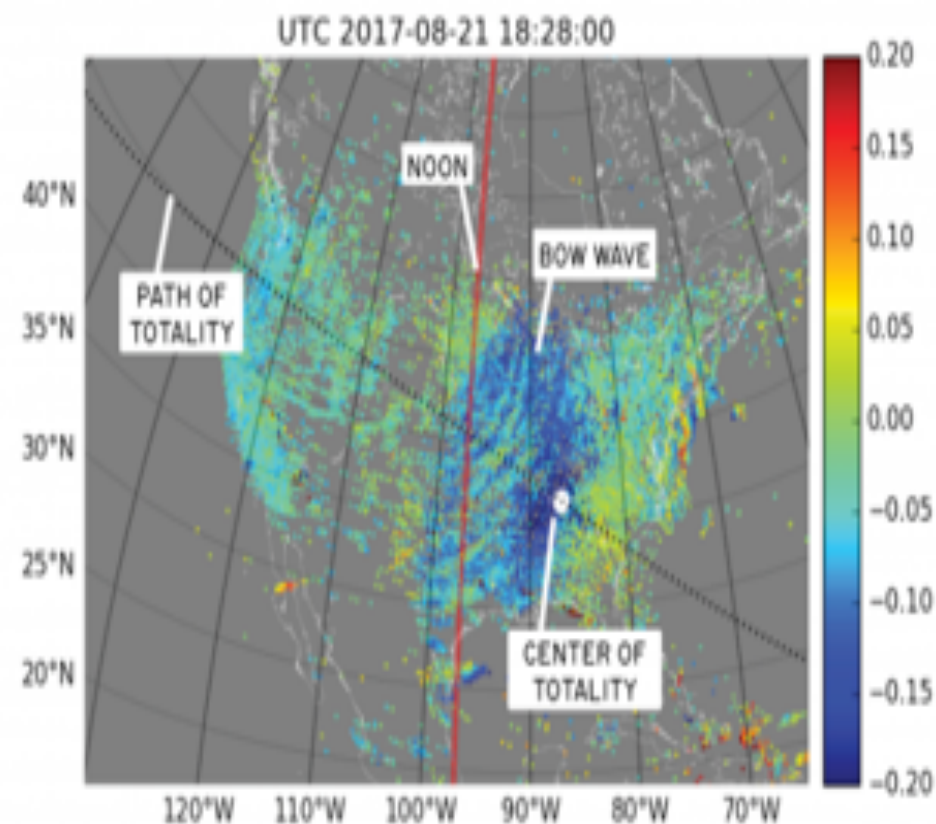


MIT WALLACE, AUGUST 2017 ECLIPSE

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This graphic shows atmospheric bow waves forming during the August 2017 eclipse over the continental United States.

Image: Shunrong Zhang/Haystack Observatory

## Solar eclipse caused bow waves in Earth's atmosphere

MIT Haystack Observatory researchers find that the moon's shadow created long-predicted ionospheric bow waves during the August eclipse.

Watch Video

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# Summary

**Structured Bow waves clearly observed following umbra.**

**Enhanced TEC observed above Rocky Mountains.  
Characteristics are being studied.**

**Mesa B/Hilton: Upper Atmosphere Responses to the  
21 August 2017 Solar Eclipse, Shunrong Zhang**