Ionospheric Variations Observed During the Solar Eclipse of August 2017

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E. Derome, J. Swoboda, G. Earle, L. Kordella, M. Moses, D. J. Knipp, and T. Bullet

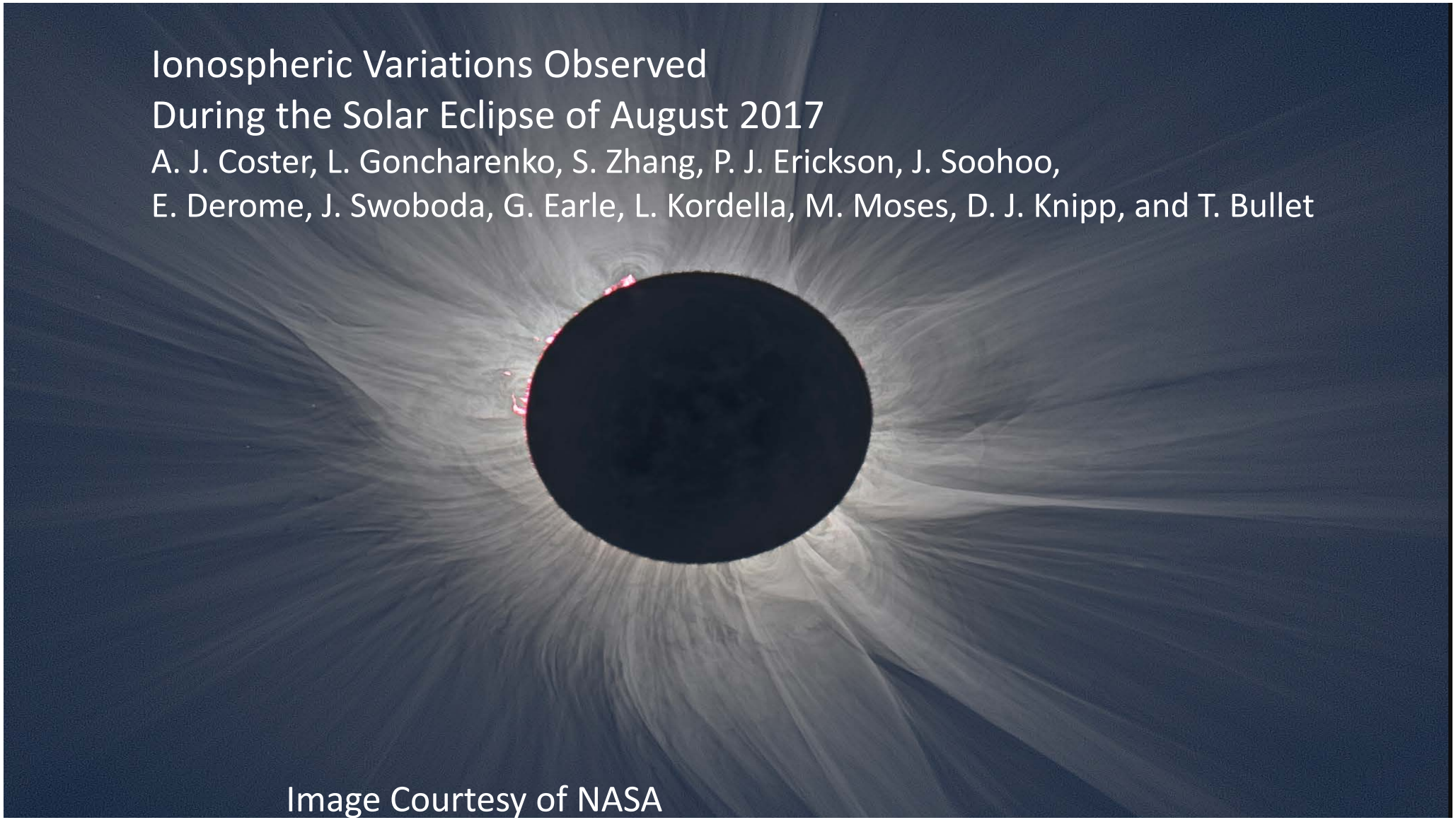


Image Courtesy of NASA


ECL7
ECL6
ECL4
ECL5
ECL3
ECL2
ECL1
BRITISH COLUMBIA
SASKATCHEWAN
ONTARIO
QUEBEC
WASHINGTON
MONTANA
NORTH DAKOTA
MINNESOTA
SOUTH DAKOTA
WISCONSIN
MICHIGAN
Ottawa
Montreal
Toronto
OREGON
IDAHO
WYOMING
NEBRASKA
IOWA
Chicago
ILLINOIS
OHIO
PENN
NEW YORK
VT
NH
MA
CT RI
MD
DE
NJ
Philadelphia
NEVADA
UTAH
COLORADO
United States
INDIANA
MISSOURI
WEST VIRGINIA
KENTUCKY
San Francisco
CALIFORNIA
Las Vegas
Los Angeles
ARIZONA
San Diego
NEW MEXICO
OKLAHOMA
TENNESSEE
ARKANSAS
Dallas
MISSISSIPPI
ALABAMA
GEORGIA
TEXAS
LOUISIANA
Houston
FLORIDA
Gulf of California
Gulf of Mexico
Mexico

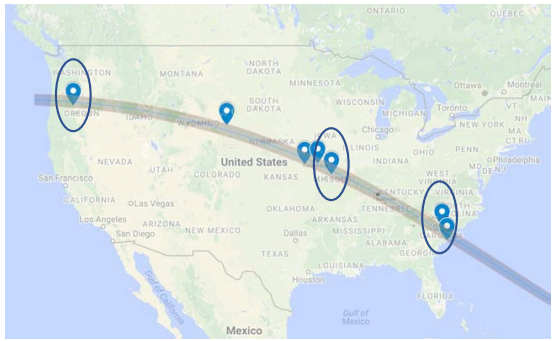
GNSS Campaign Overview for Aug 21st Solar Eclipse

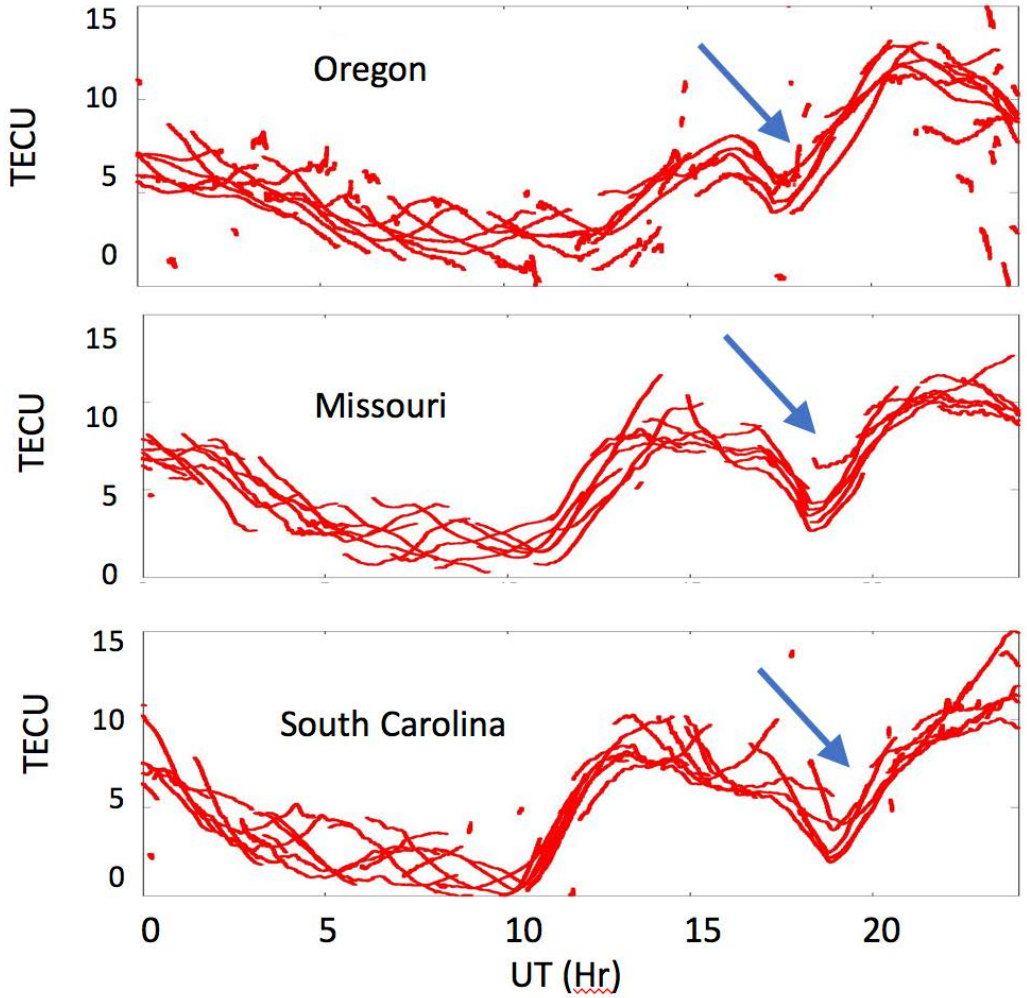
5 GNSS receivers borrowed from UNAVCO, 2 borrowed from MIT

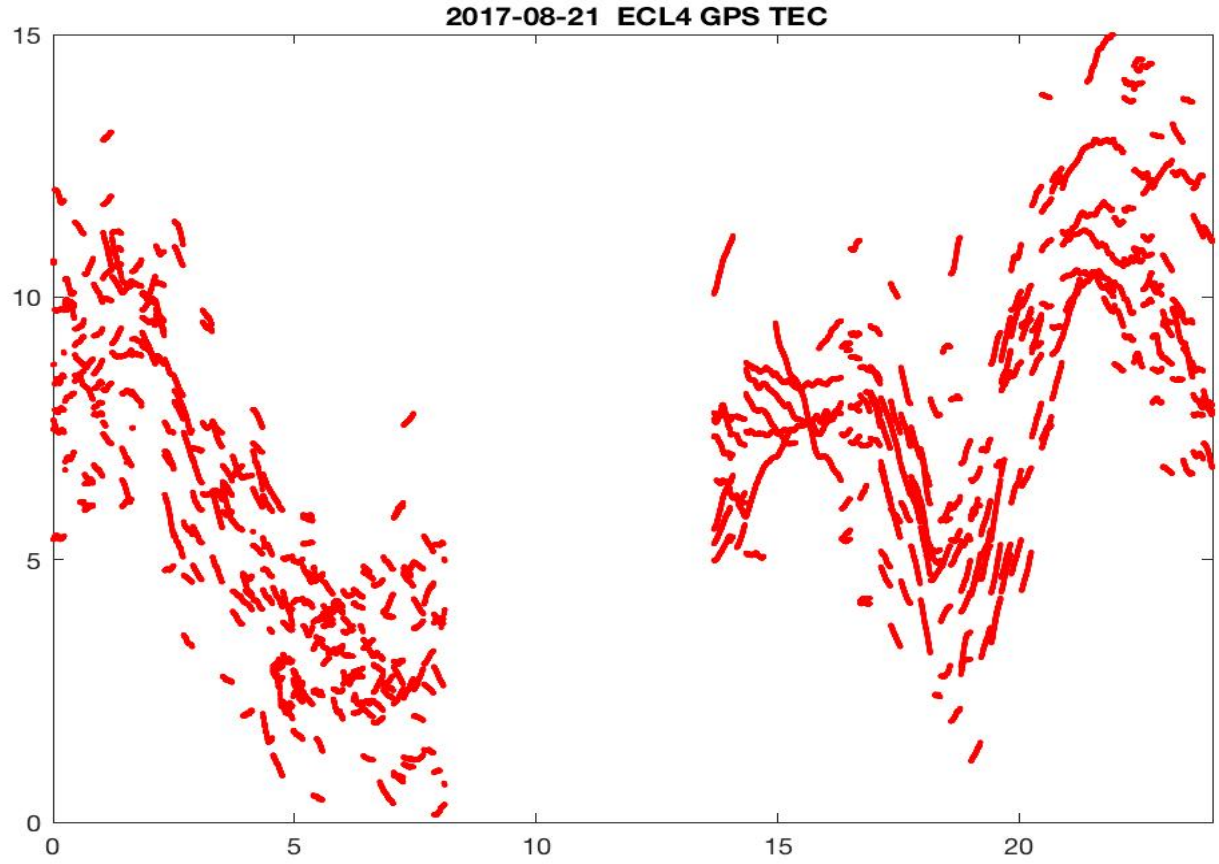
- 7 sites have been identified
  - Tom Clark (NEROC) – SC
  - Greg Earle (VT) – SC
  - Magda Moses (VT) – KS
  - John Hubbard (NRL) – MO
  - Delores Knipp (U. Colorado) – MO
  - John Swoboda (MIT) & Terry Bullett (NOAA) – WY
  - Lee Kordella (VT) – OR
- GPS data transferred back to Haystack in near real-time

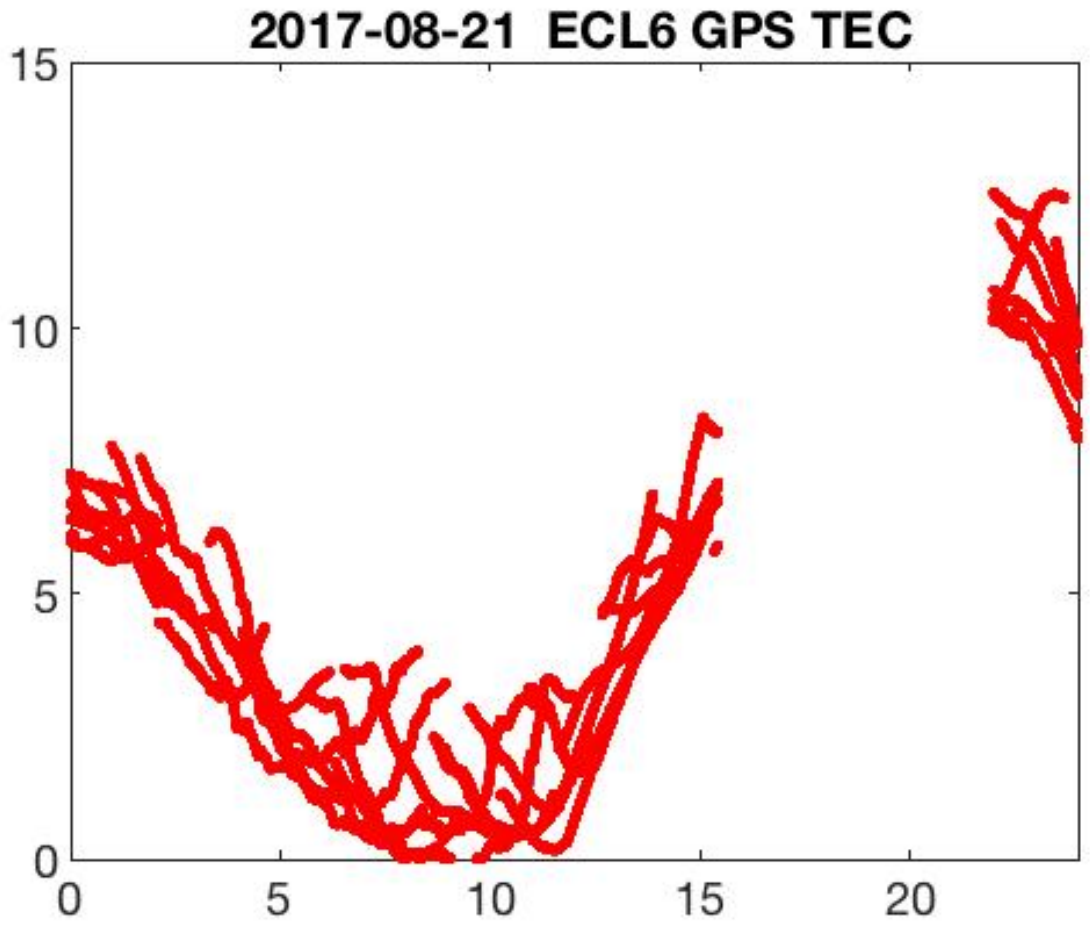
UNAVCO RECEIVER
SETUP

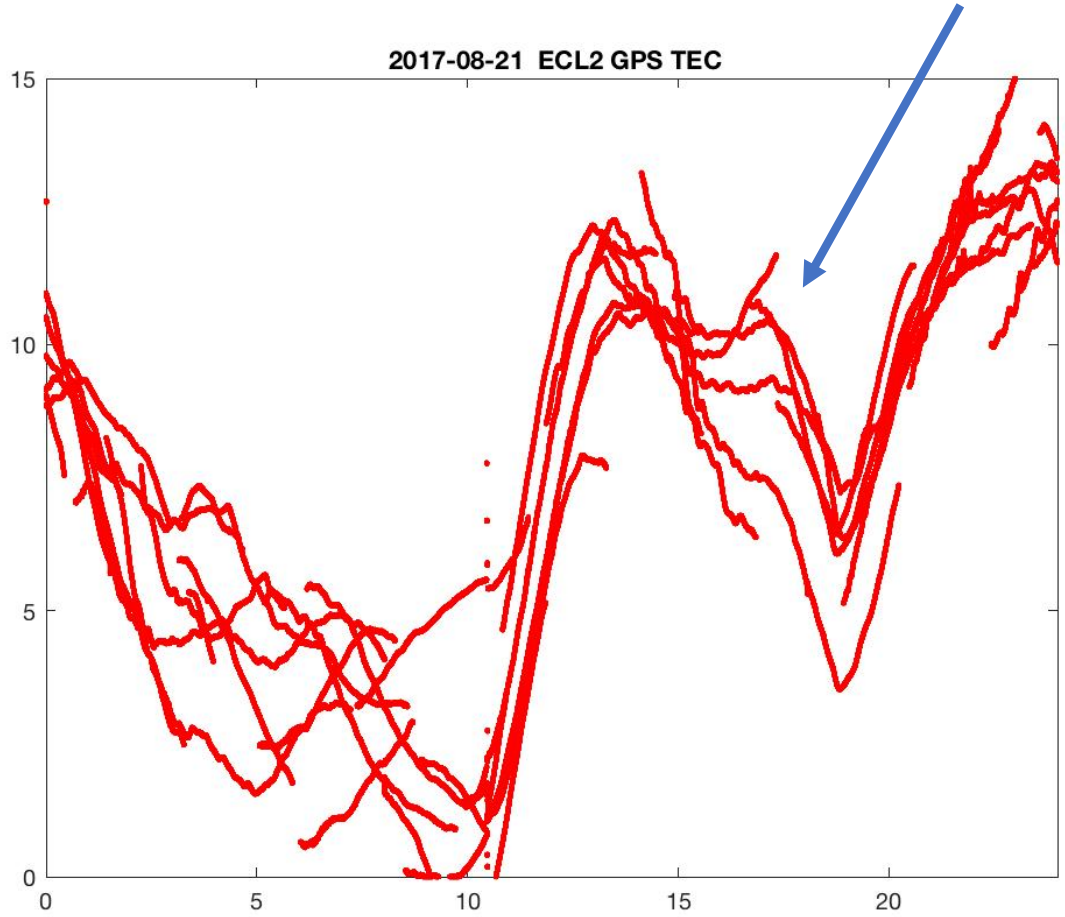
Delores Knipp’s 90 year old father

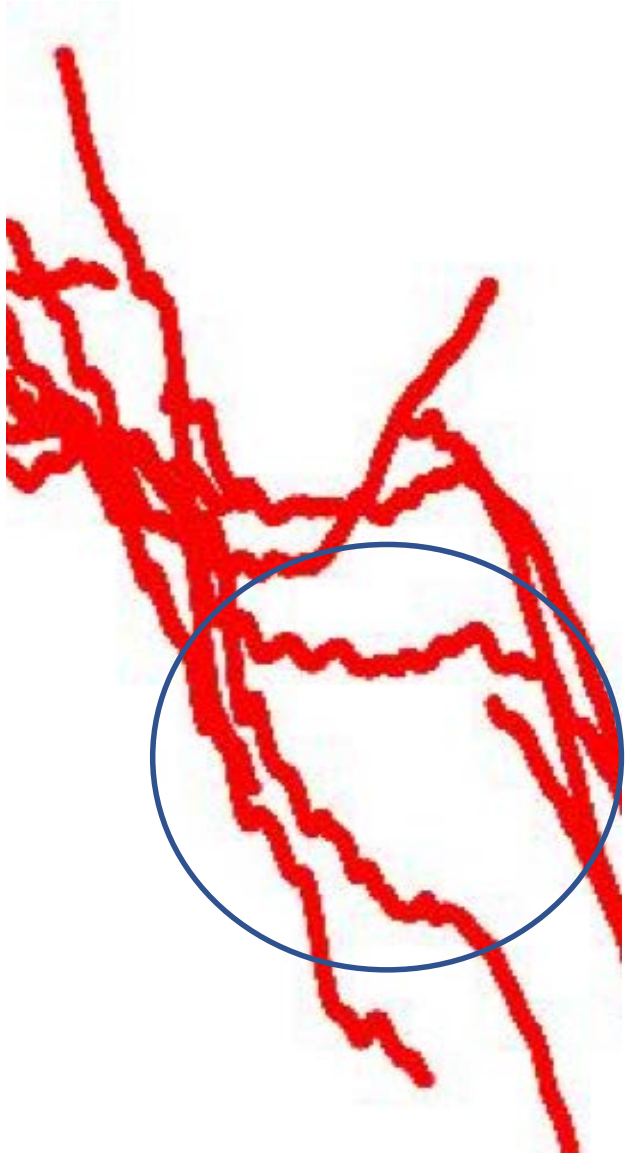

United States
Mexico


Oregon
Missouri
South Carolina
TECU
TECU
TECU
15
10
5
0
15
10
5
0
15
10
5
0
0
5
10
15
20
UT (Hr)

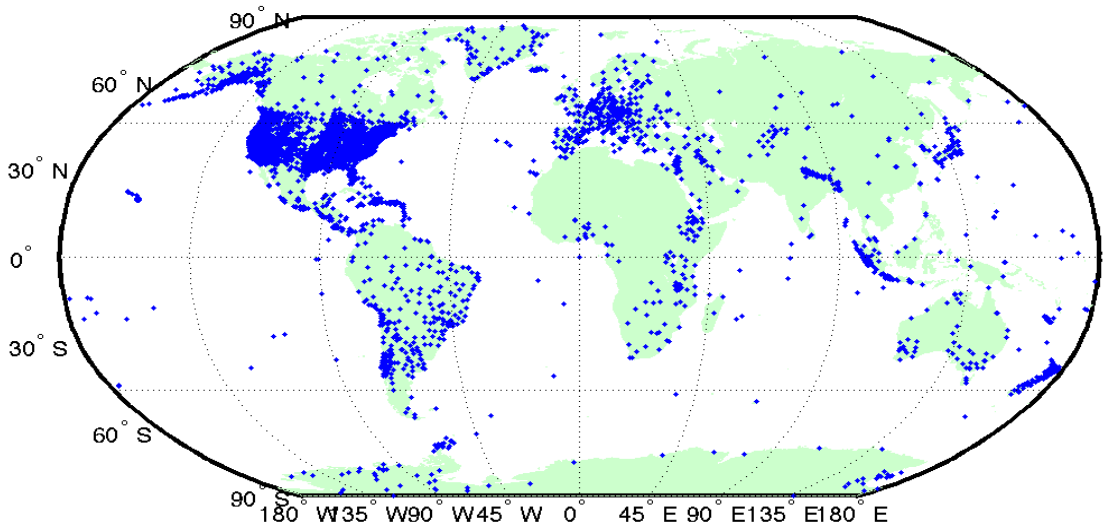

2017-08-21 ECL4 GPS TEC
15
10
5
0
0
5
10
15
20

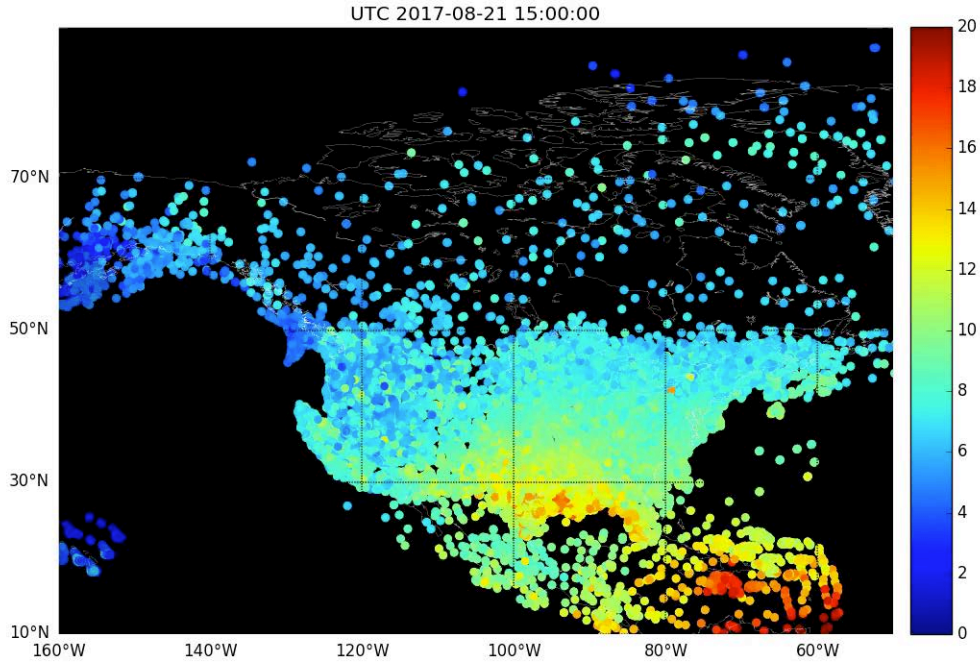

2017-08-21 ECL6 GPS TEC
15
10
5
0
0
5
10
15
20

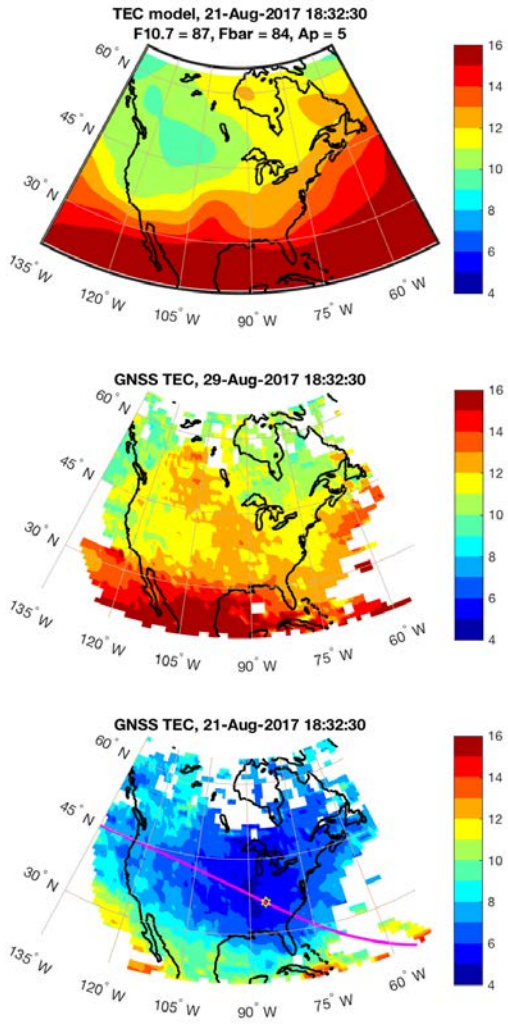

2017-08-21 ECL2 GPS TEC
15
10
5
0
0
5
10
15
20



Map of ~ 3000 GPS receivers




UTC 2017-08-21 15:00:00
70°N
50°N
30°N
10°N
160°W
140°W
120°W
100°W
80°W
60°W
20
18
16
14
12
10
8
6
4
2
0

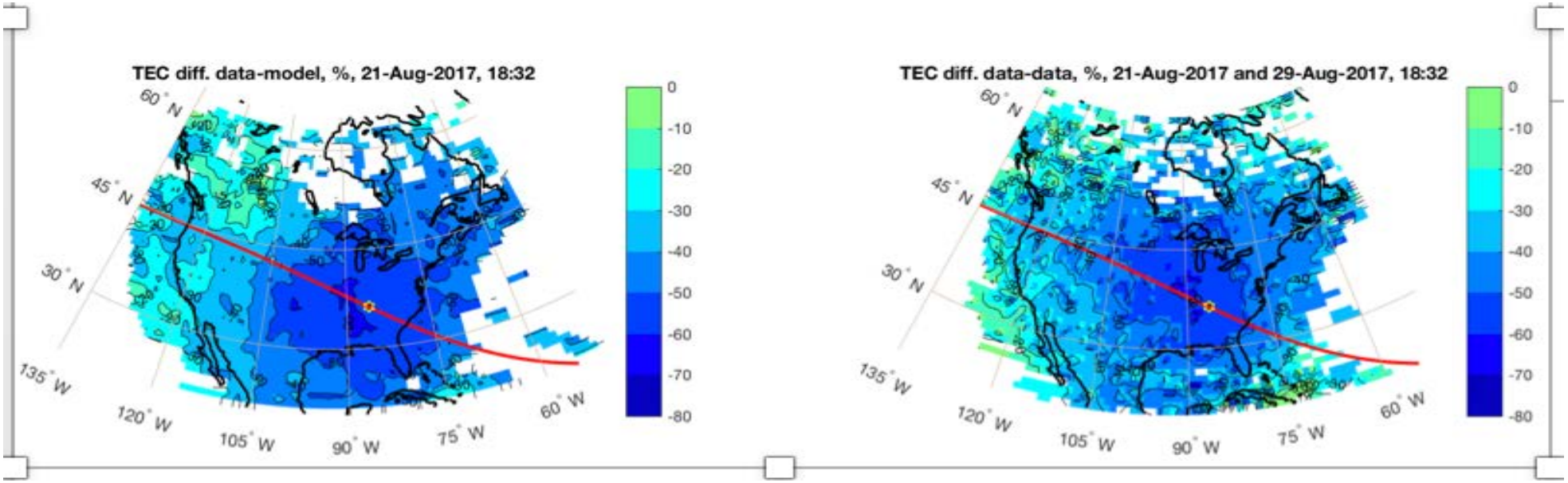


How large is the 'ionospheric hole' due to the eclipse?

- The answer depends on the selection of a baseline. We tried 2 methods, empirical TEC model (NATEC, Chen et al., 2015) and observations.
- Top panel: NATEC results (F10.7 = 87, Fbar = 84, Ap=5). North America TEC model works well and is a good indicator of expected behavior in TEC
- Middle panel: Observations for Aug 29, 2017, closest day with similar F10.7 (F10.7 = 84). Shows little lower TEC overall and a patch of higher TEC at 90-110W.
- Bottom panel: Observations for Aug 21, 2017; much lower TEC over entire continental US.

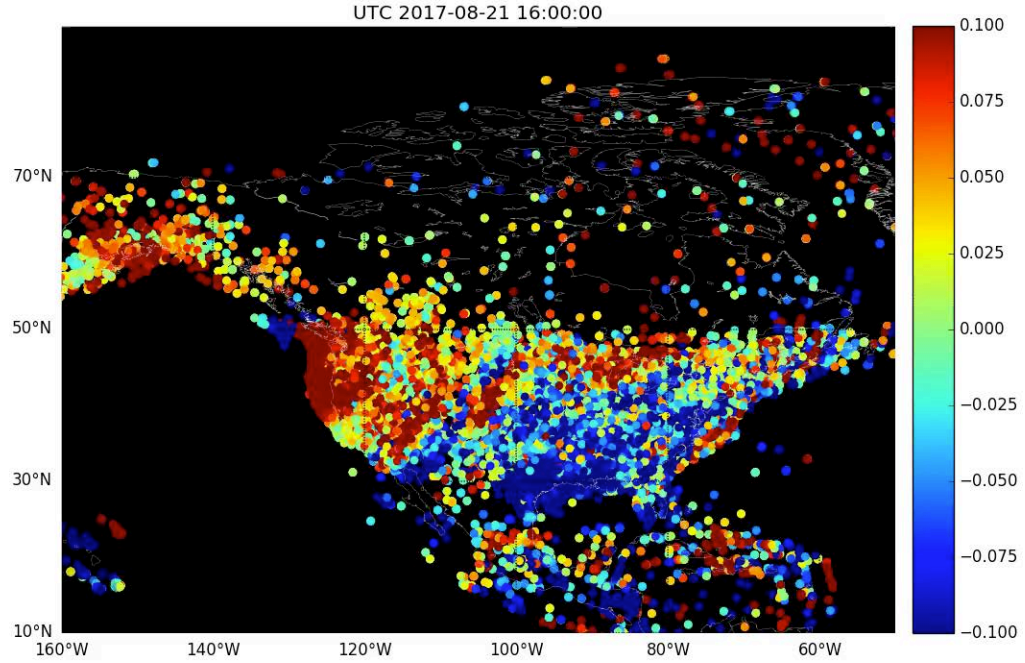
- ***Results are very similar, regardless of a choice of control day***
- ***Largest decrease >60% is to the west of totality; shows nicely in model-data and data-data differences***

Comparison of eclipse data (Aug 21) with NATEC model (left) and Aug 29, 2017 data



TEC **data-model** difference in relative difference in % (bottom); Max decrease in TEC is 6-8 TECu, 50-60%

TEC **data-data** difference in relative difference in % (bottom); Max decrease in TEC is 6-8 TECu, 50-60%


UTC 2017-08-21 16:00:00
70°N
50°N
30°N
10°N
160°W
140°W
120°W
100°W
80°W
60°W
0.100
0.075
0.050
0.025
0.000
−0.025
−0.050
−0.075
−0.100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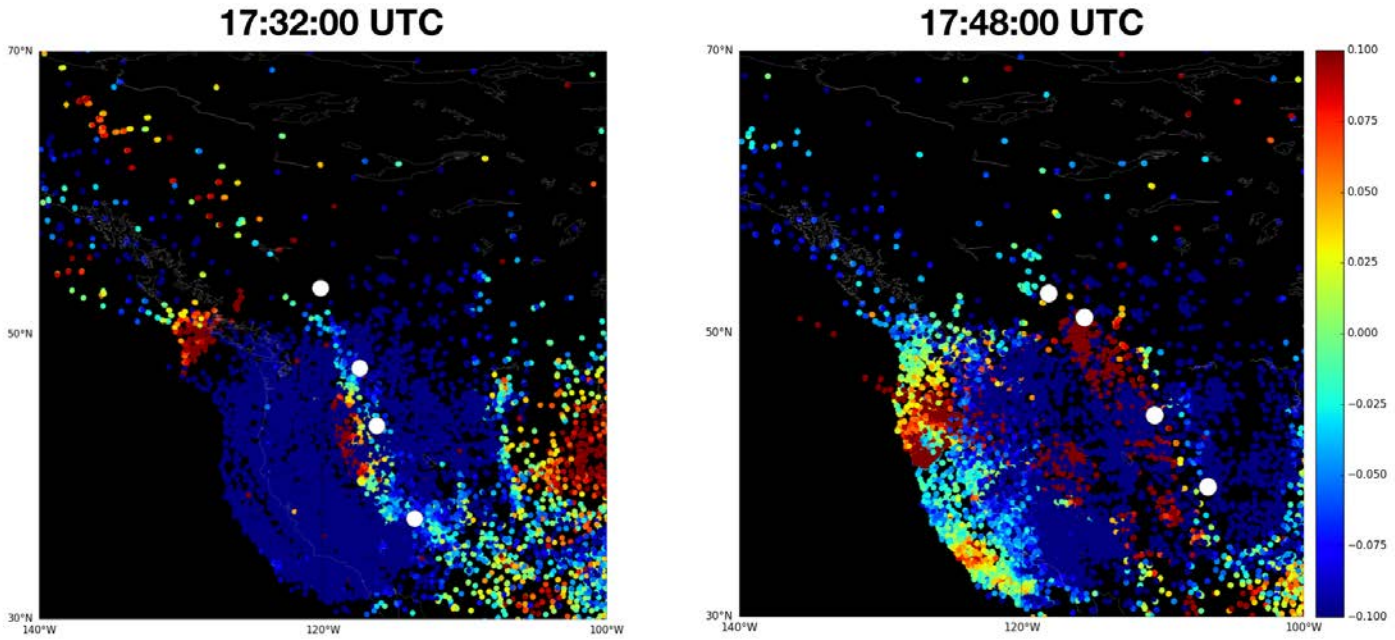
Arctic Ocean
(Russia)
ASIA
Beaufort Sea
Brooks Range
Alaska Range
Coast Ranges
Rocky Mountains
GREAT PLAINS
CANADIAN SHIELD
Hudson Bay
Labrador Sea
Gulf of Alaska
Bering Sea
Great Lakes
Pacific Ocean
Cascades
Sierra Nevada
Appalachian Mts.
COASTAL PLAIN
Atlantic Ocean
600 mi
600 km
Gulf of Mexico
Sierra Madres
CARIBBEAN
NORTH AMERICA
Caribbean Sea
CENTRAL AMERICA
worldatlas
Pacific Ocean
SOUTH AMERICA

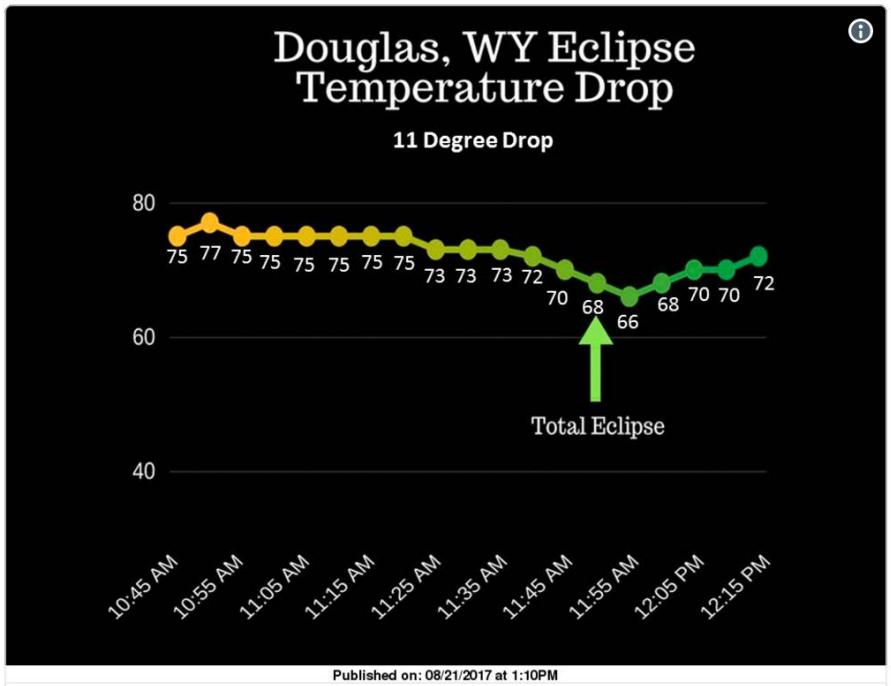
Evidence of enhanced TIDs on
the western side and eastern side of the Rocky Mountain range.



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

Changes in Temperature

- The Great American Eclipse will start about 9 a.m. in Oregon with the path of totality crossing 14 states as it makes its way to South Carolina. The path of totality - the area that will experience the greatest periods of darkness - will also see the largest changes in daytime temperature.
- "When sunlight fades at twilight, we always notice how things start to cool down. The same is true for the temporary dimming during a total solar eclipse," NASA said.
- The amount of temperature drop will depend on factors such as time of year, cloud cover and the length of totality. In some scenarios, the air temperature can drop more than 20 degrees F, though this eclipse will more than likely see changes around the 10 degree mark.
- The change will be less dramatic in areas outside the path of totality.



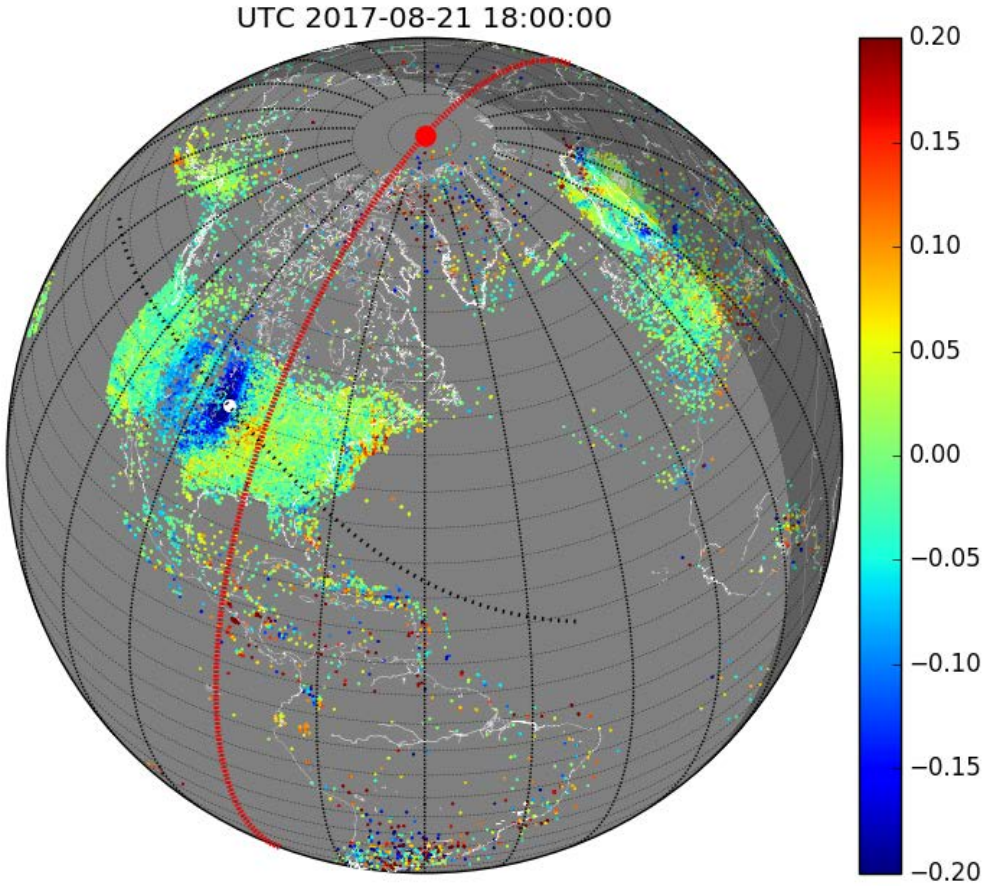
NWS Cheyenne ✓
@NWSCheyenne

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



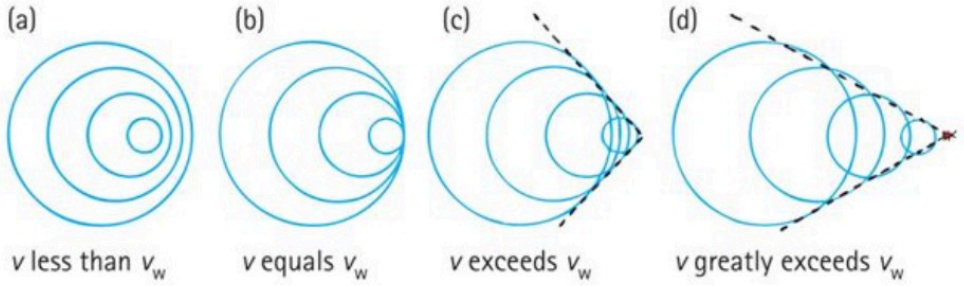
Differential TEC using S-G filter with a 2 hour sliding window and a linear basis function.

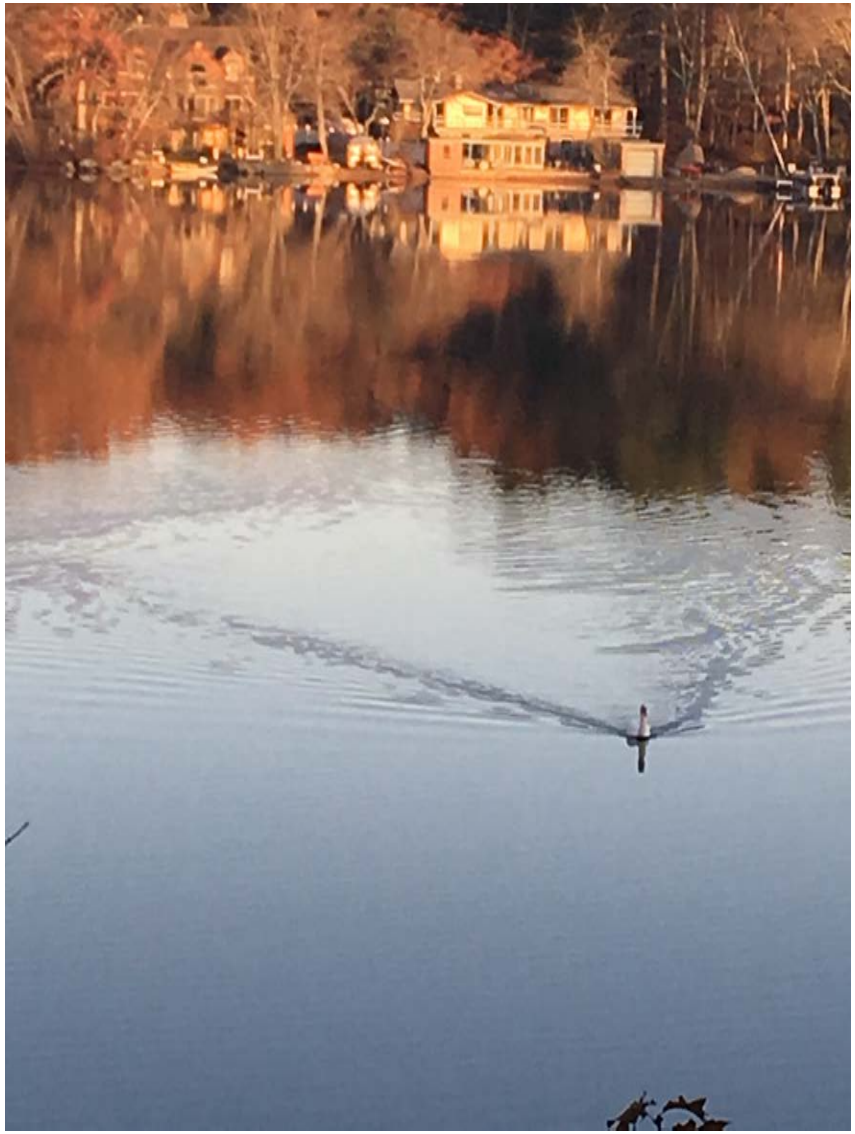
The 2 hr window was used because of the the eclipse (partial or totality) took about 2 hrs at a given location

Red line is noon meridian
White dot: totality location

Bow Waves

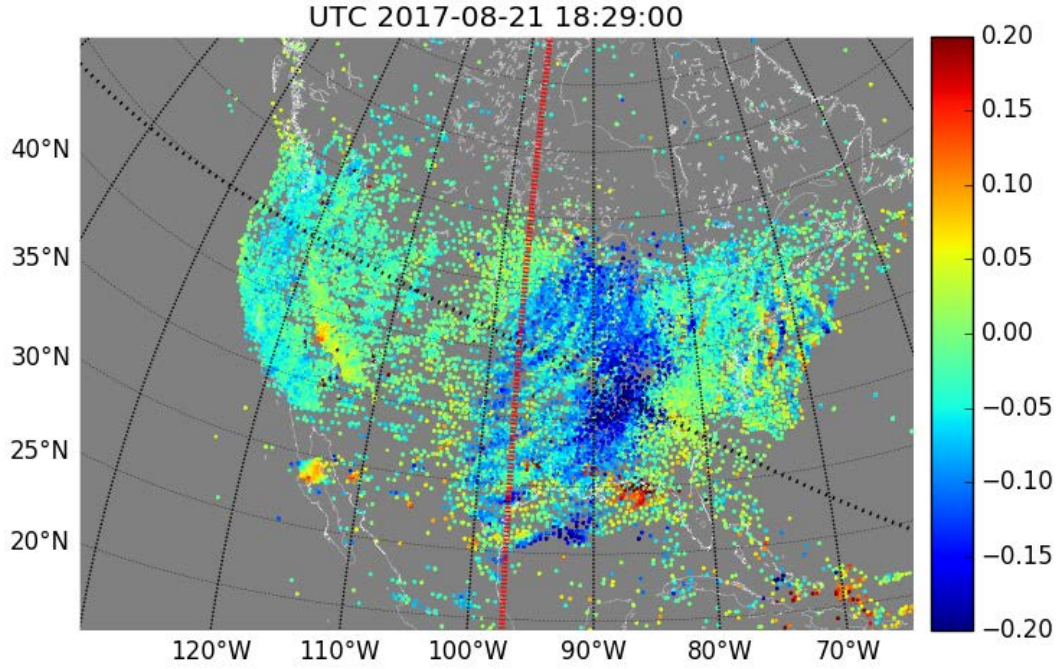
- Supersonic
  - Aircraft flying faster than the speed of sound.
- Bow wave
  - V-shape form of overlapping waves when object travels faster than wave speed.
  - An increase in speed will produce a narrower V-shape of overlapping waves.





bow waves

W=121, n=1



Conclusion

- 50-60% depletion in electron density observed, greater than models predicted
- Research into eclipse effects on ionosphere continuing

The whole (hole) is greater than

the sum of its parts