# Solar flare caused ionospheric disturbances measured with a dense GPS TEC network and an incoherent scatter radar

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**MIT Haystack Observatory**


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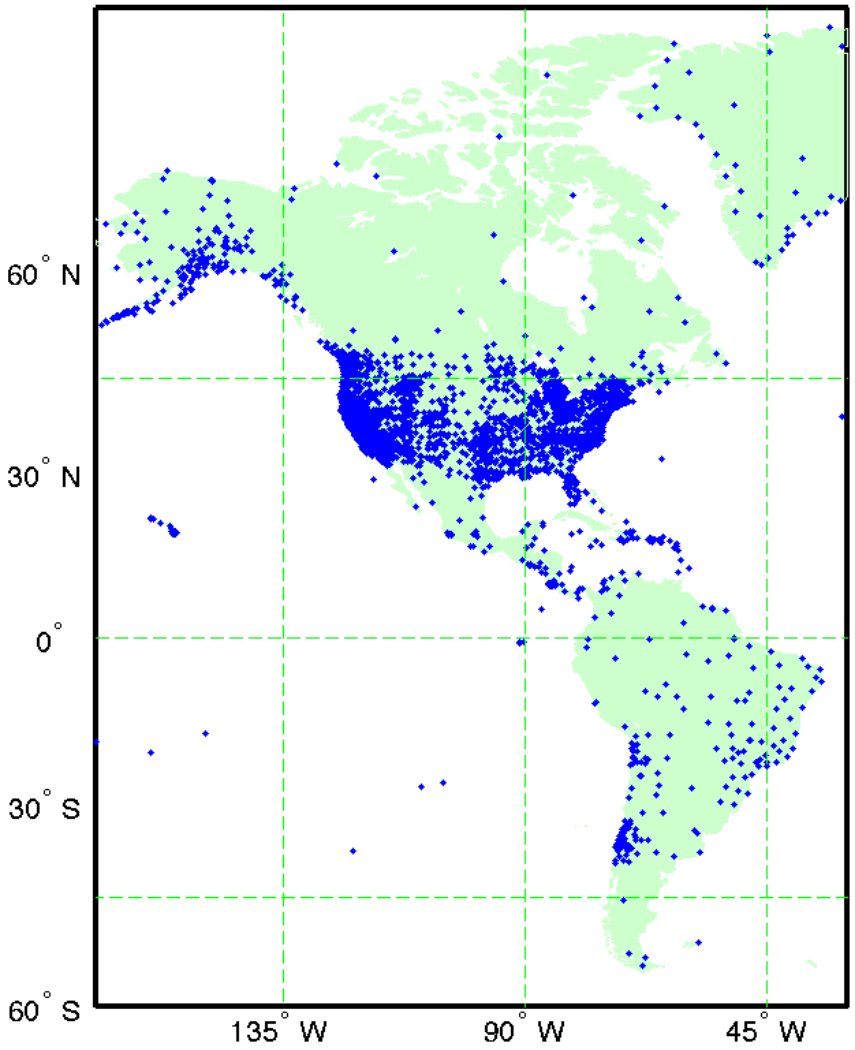
# Outline

- Solar flare effects on the ionosphere
  - What's new?
- Observations
  - Dense networks of GPS receivers for ionospheric research
  - Incoherent scatter radars
- Flare case studies
  - Global TEC
  - TEC Latitudinal variations
  - LSTID
  - ISR
- Conclusion

# GPS Data Processing at MIT

- Sites are growing:
  - close to 6000
- New generation of data products
  - Improved bias estimate
  - Differential TEC later 2016
  - LOS available later 2016
  - 1x1 (lat x lon), 20 min
- All data online
  - http://openmadrigal.org



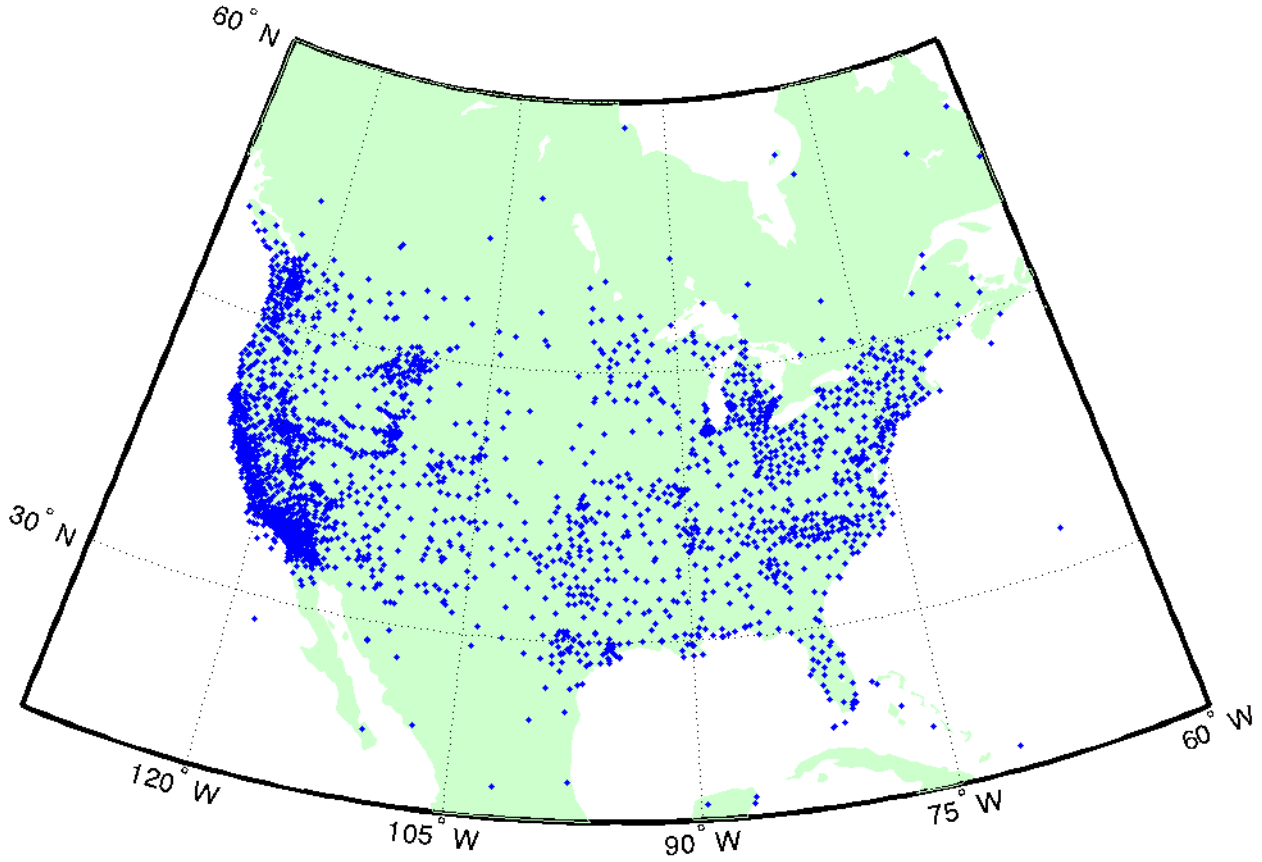

**Contact Anthea Coster (ajc@mit.edu)**

Massachusetts Institute of Technology

HAYSTACK

MIT Millstone Hill Observatory

# GPS sites (NA) in the MIT TEC system (as of 2014)



# http://openmadrigal.org

Madrigal home page

Instrument:
World-wide GPS Receiver Networ 1998-2016

Year:
2005

Month:
September

**September 2005**

| Sun | Mon | Tue | Wed | Thu | Fri | Sat |
|---|---|---|---|---|---|---|
| 28 | 29 | 30 | 31 | 01 | 02 | 03 |
| 04 | 05 | 06 | 07 | 08 | 09 | 10 |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 25 | 26 | 27 | 28 | 29 | 30 | 01 |

Selected Instrument:
- *World-wide GPS Receiver Network*
- PI: Anthea Coster - please contact before using this data

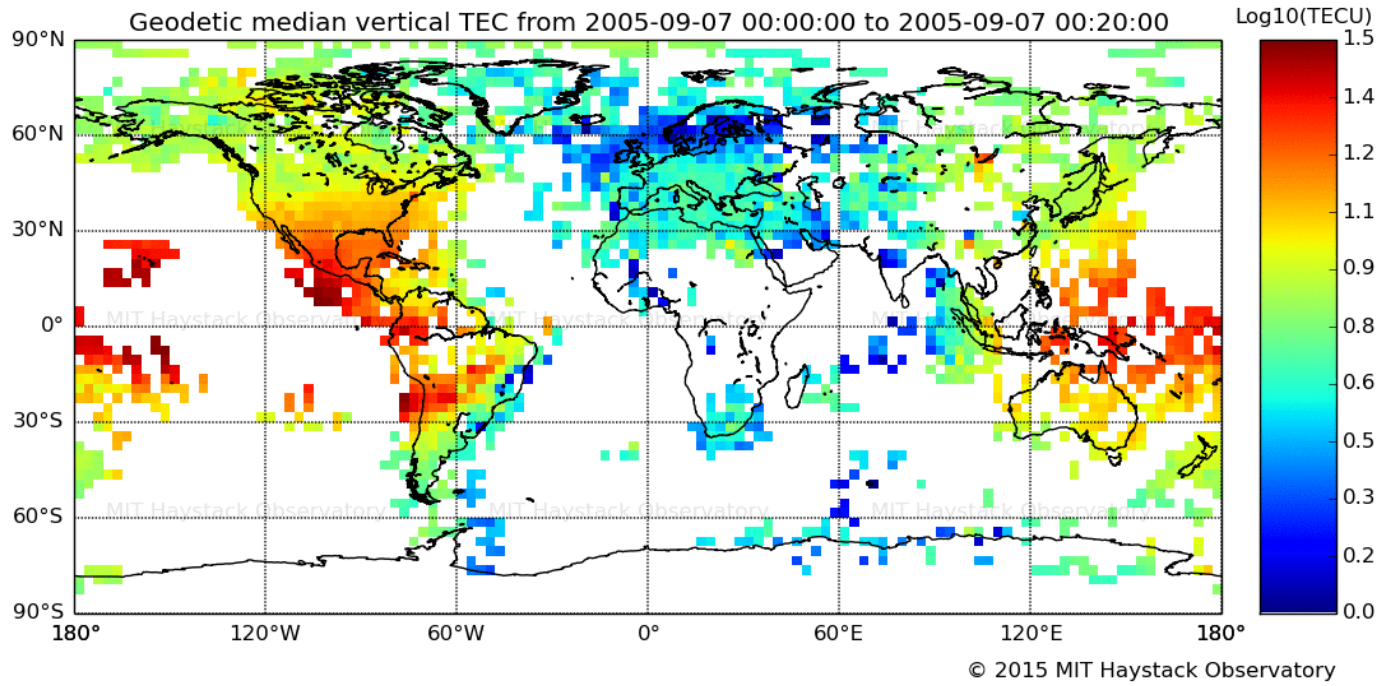
Experiment: World-wide Vertical Total Electron Content: 2005-09-07 00:00:00 - 2005-09-08 00:00:00

Select File:
gps050907g.003: Minimum Scallop TEC Processing - final

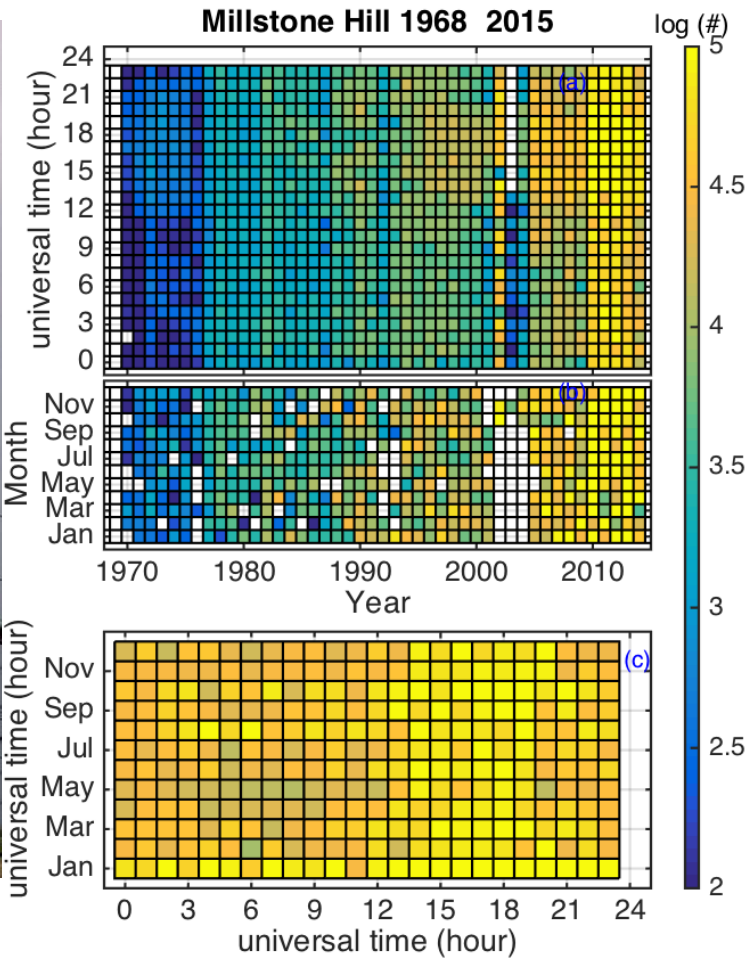
Selected date:
- 2005-09-07

Email me if this experiment OR if any World-wide GPS Receiver Network experiment is updated.

Download data | Print data | View info | Show Plots | More parameters



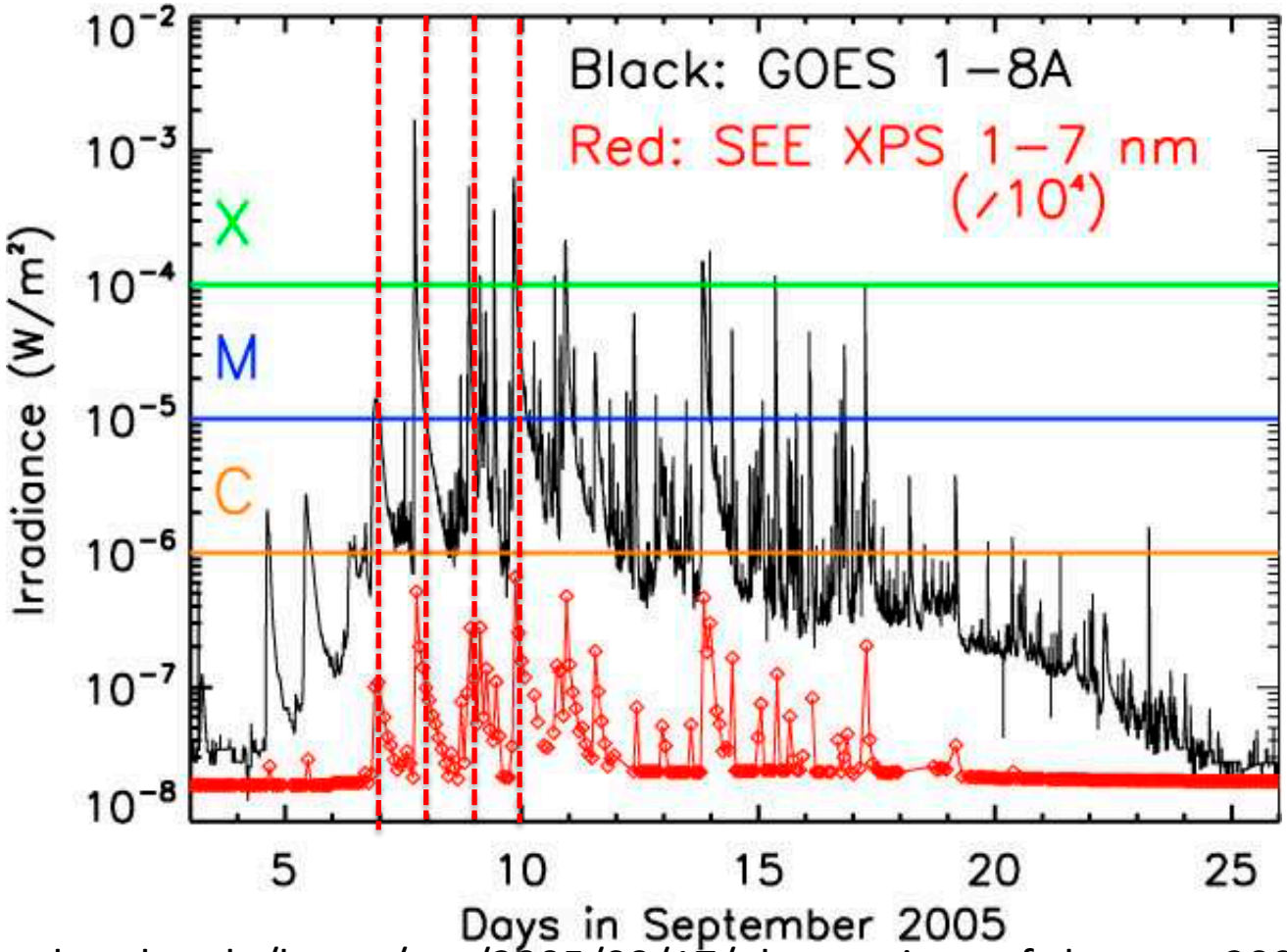
# Millstone Hill Incoherent Scatter Radar (1960+ - present)




**http://openmadrigal.org**

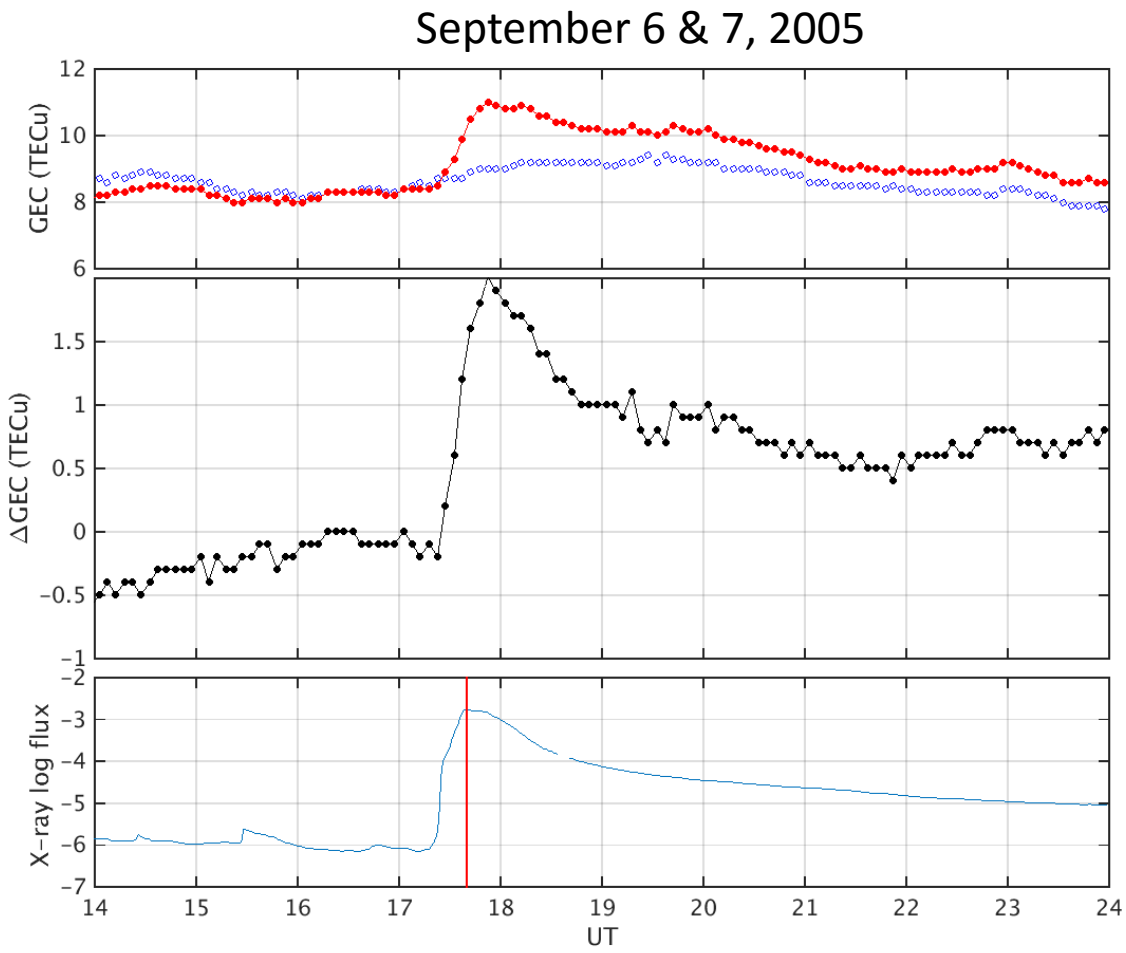
# Solar flares in Sept 2005

- Sept 7, 8, 9 (2015)

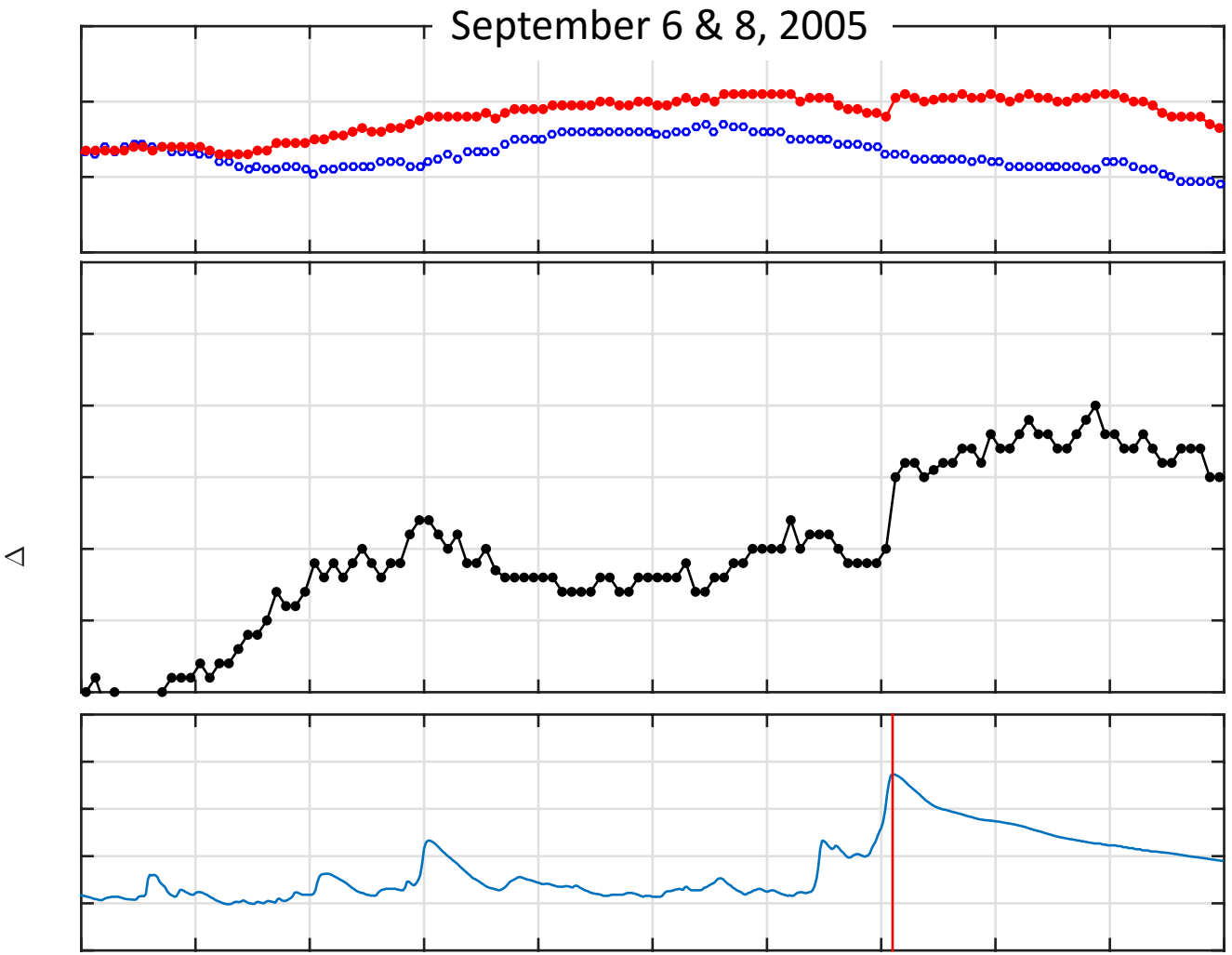



http://lasp.colorado.edu/home/see/2005/09/17/observations-of-the-sept-2005-solar-storm/

# Global Electron Content (GEC) Response

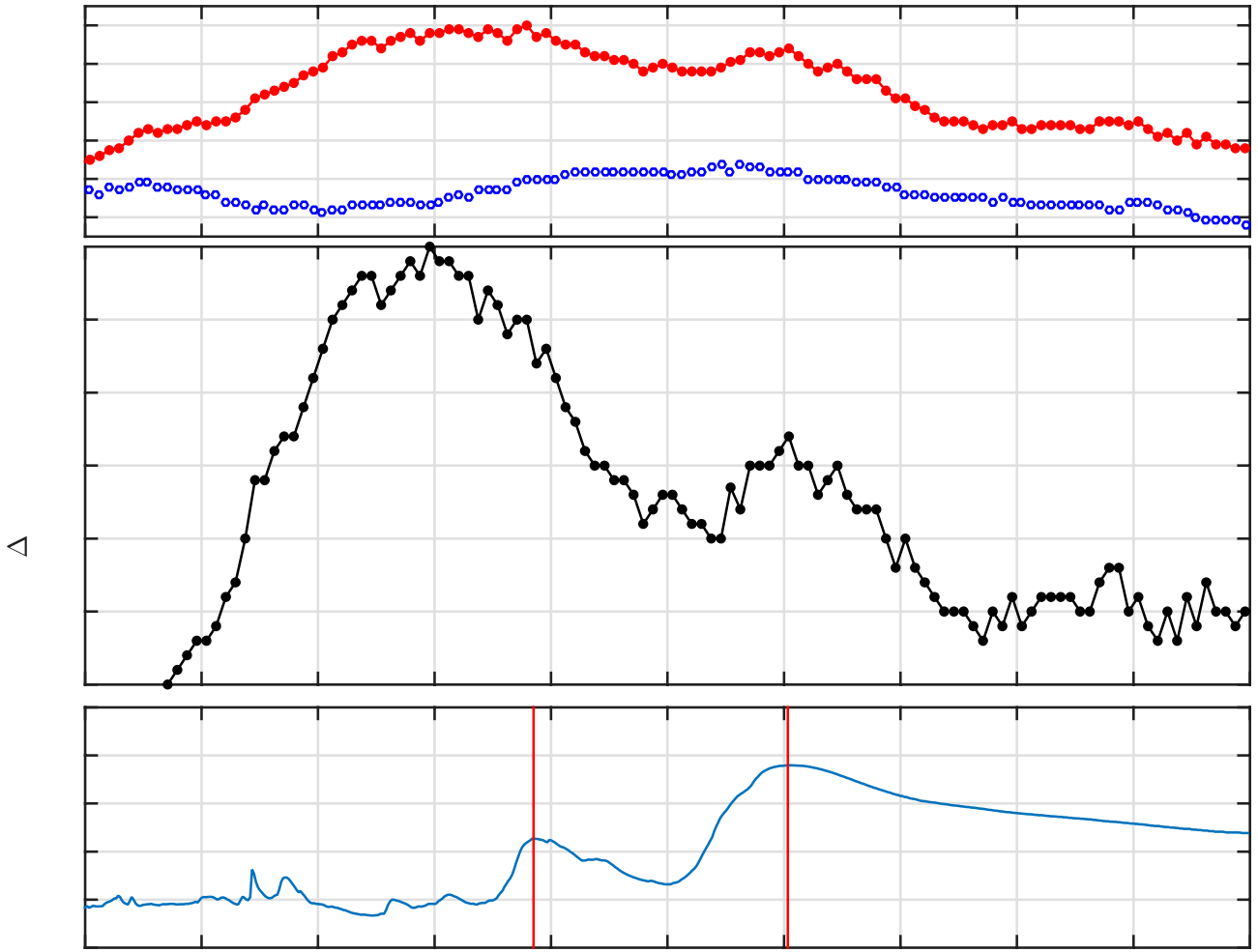


# GEC

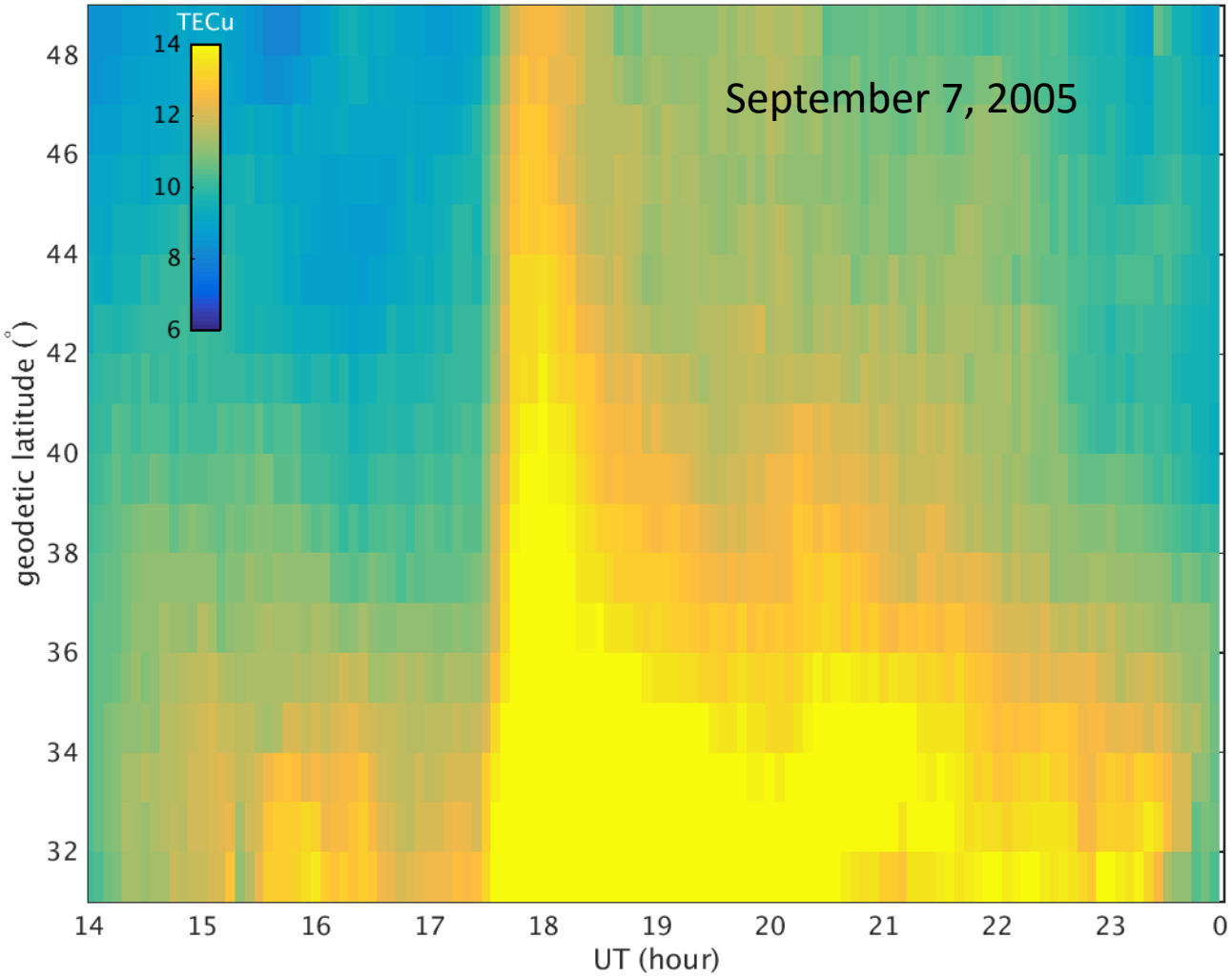


# GEC

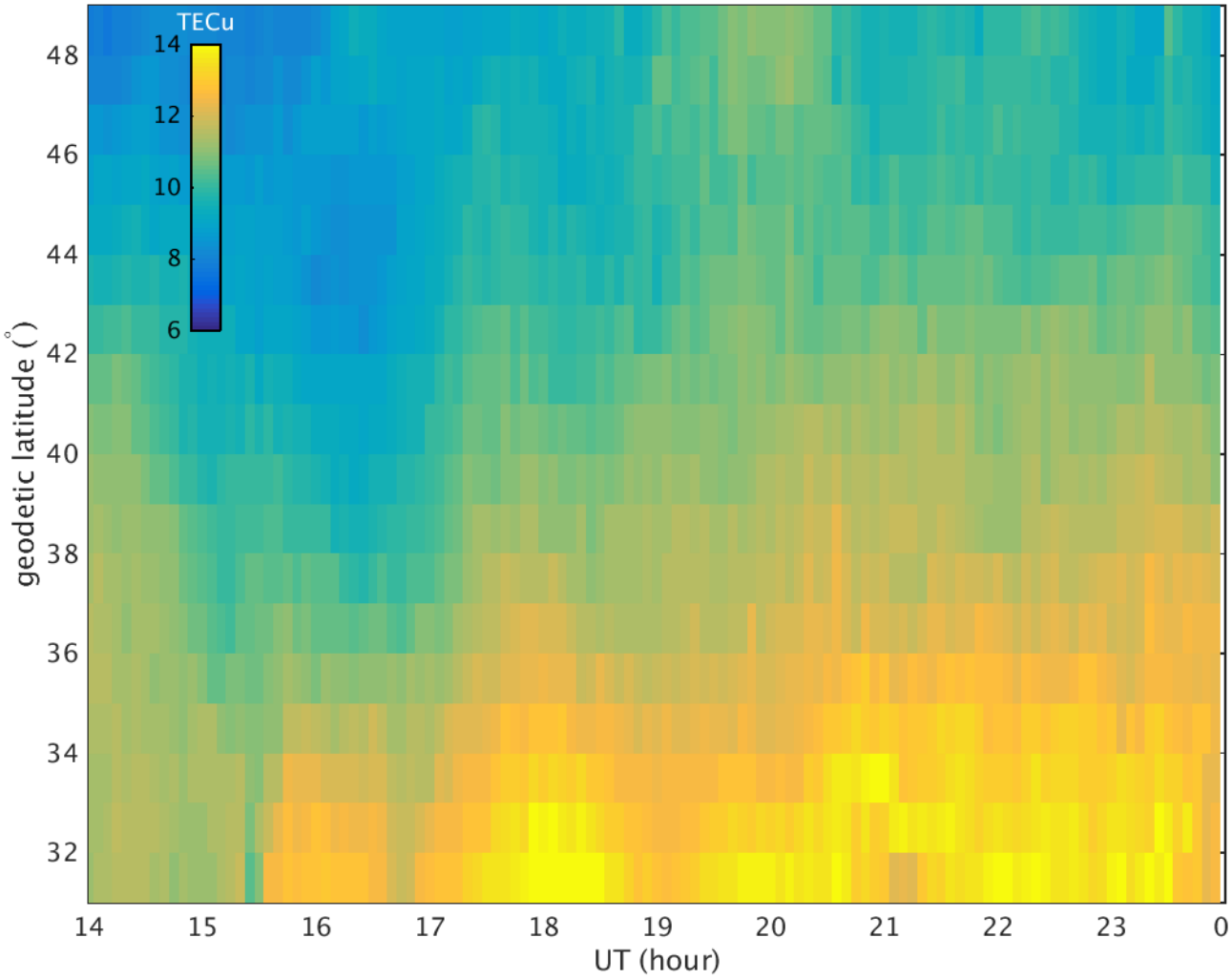
September 6 & 9, 2005



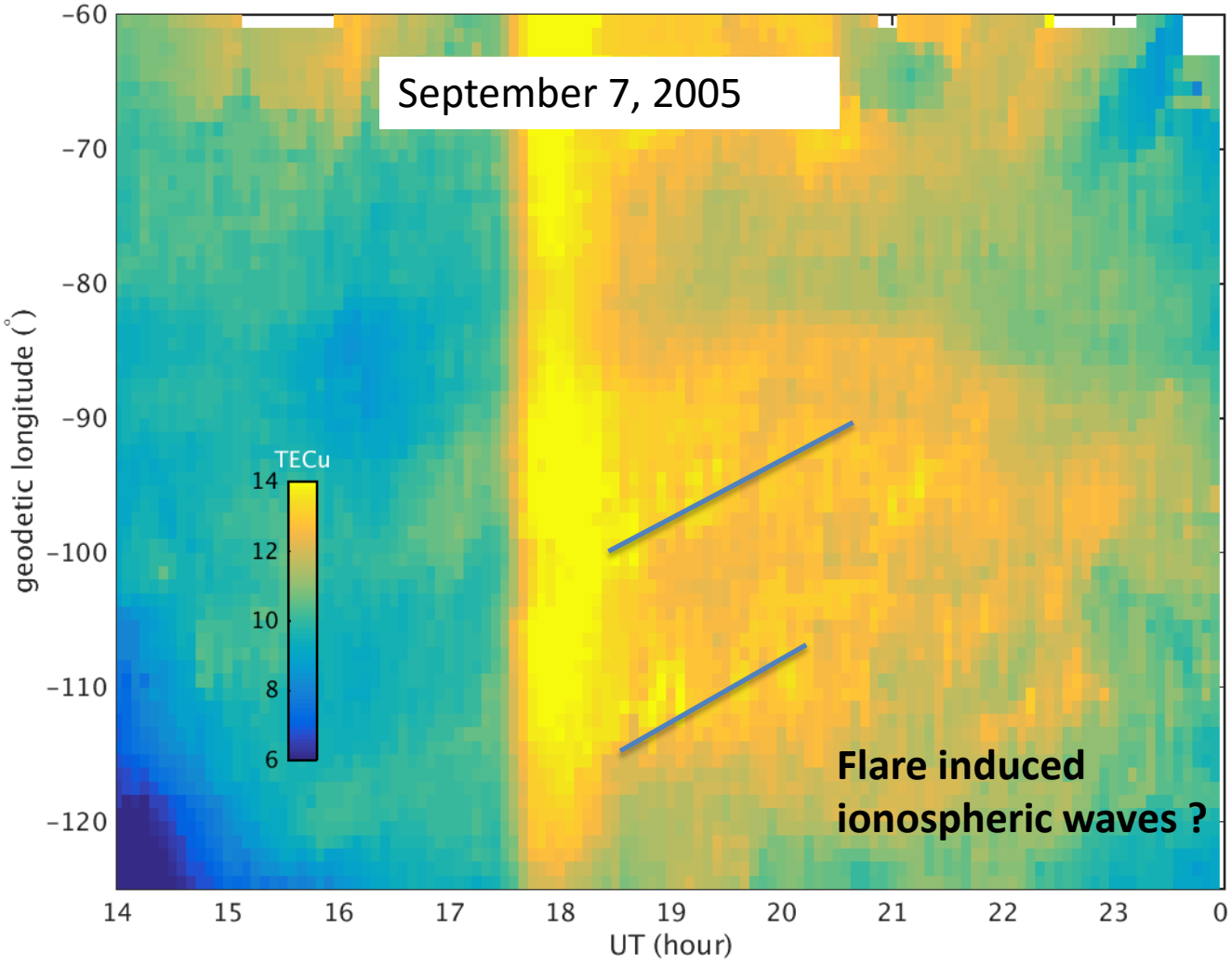
# TEC latitudinal variation @ 75W



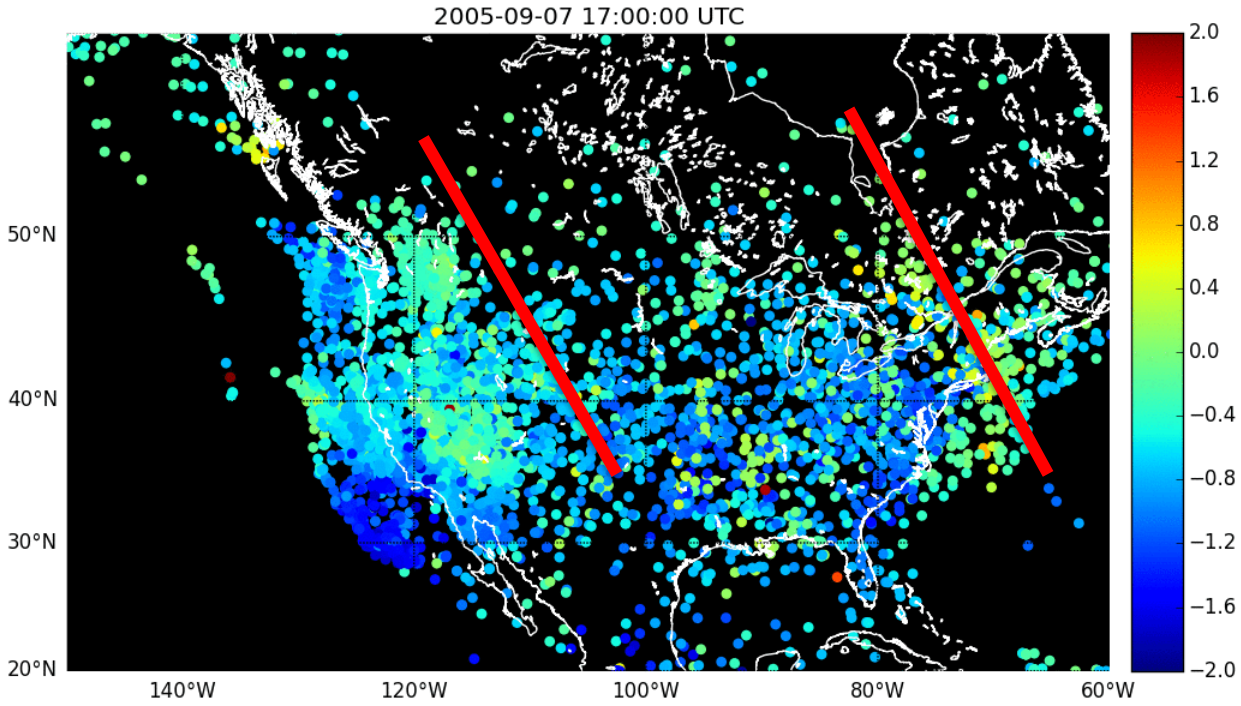
# September 6, 2005



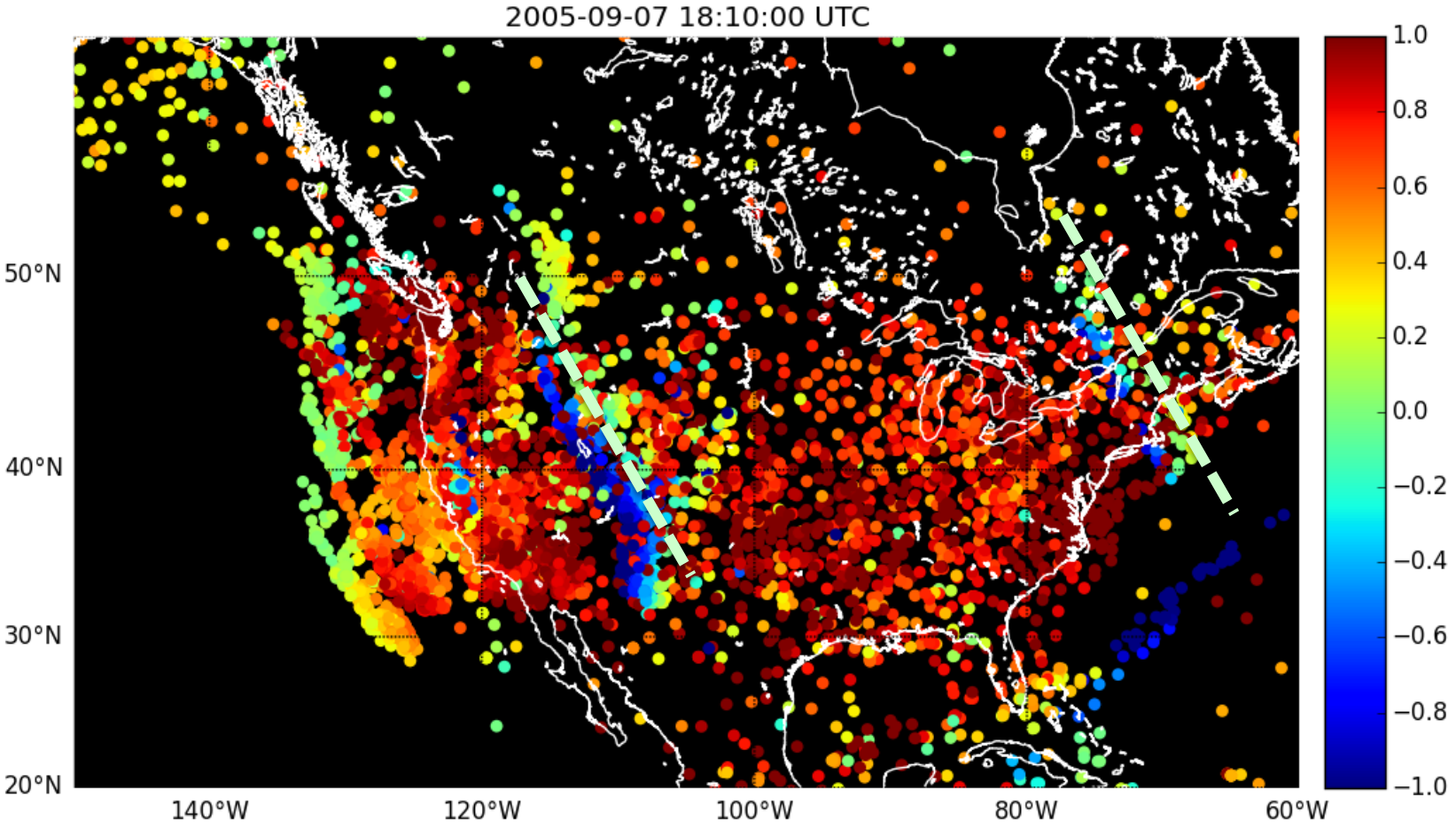
# TEC longitudinal variations @40N



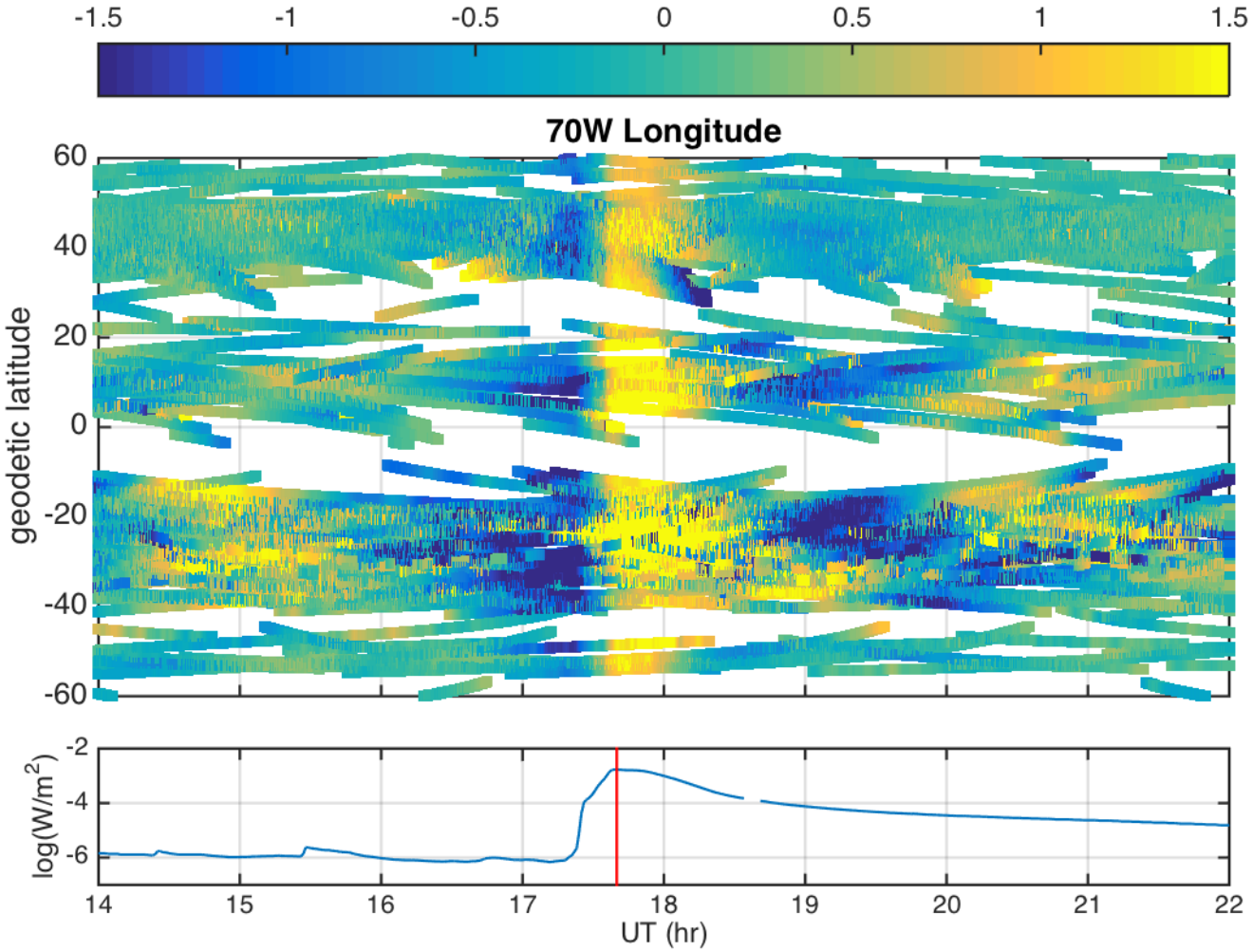
# Differential TEC: LSTIDs



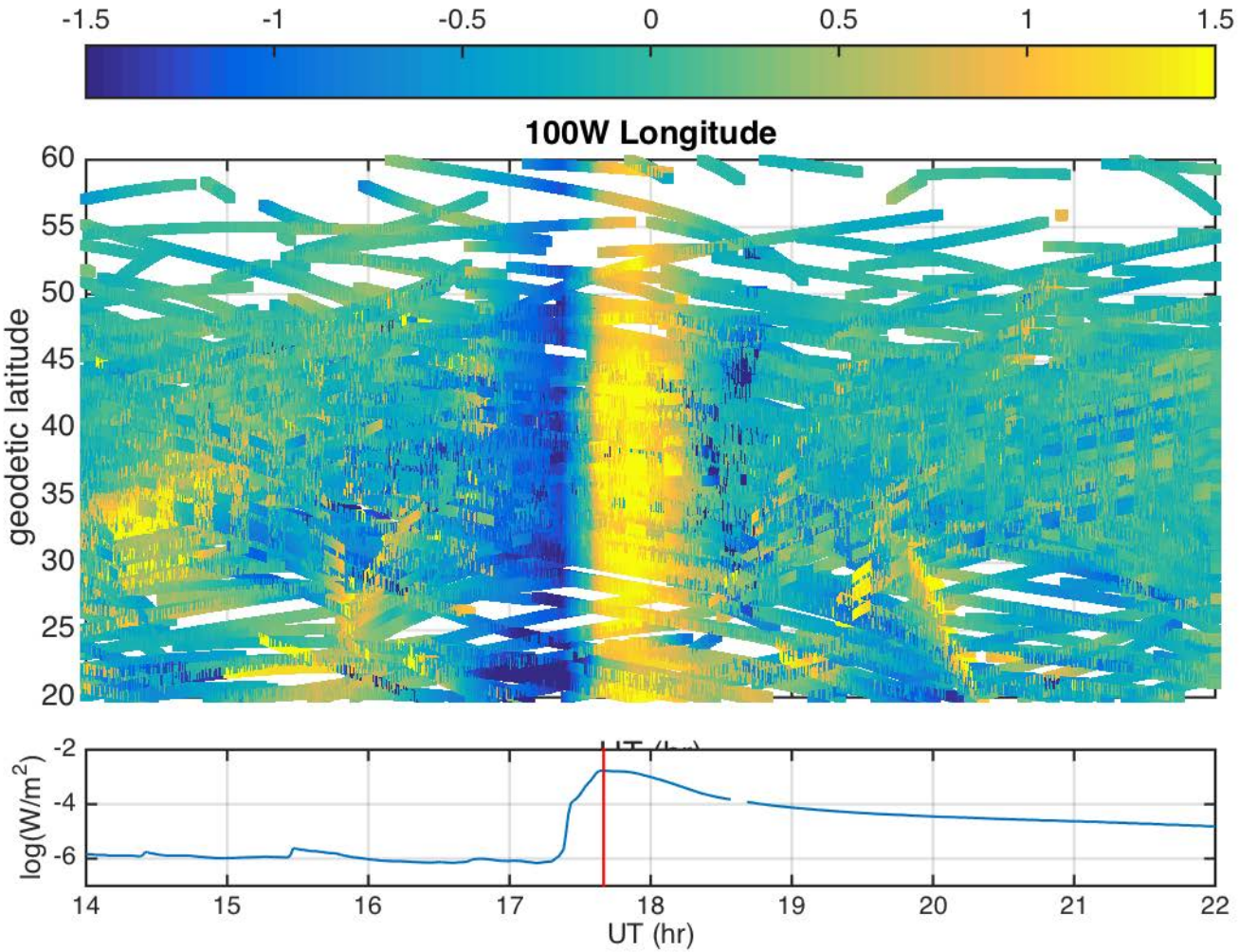
# Differential TEC: Two wave fronts



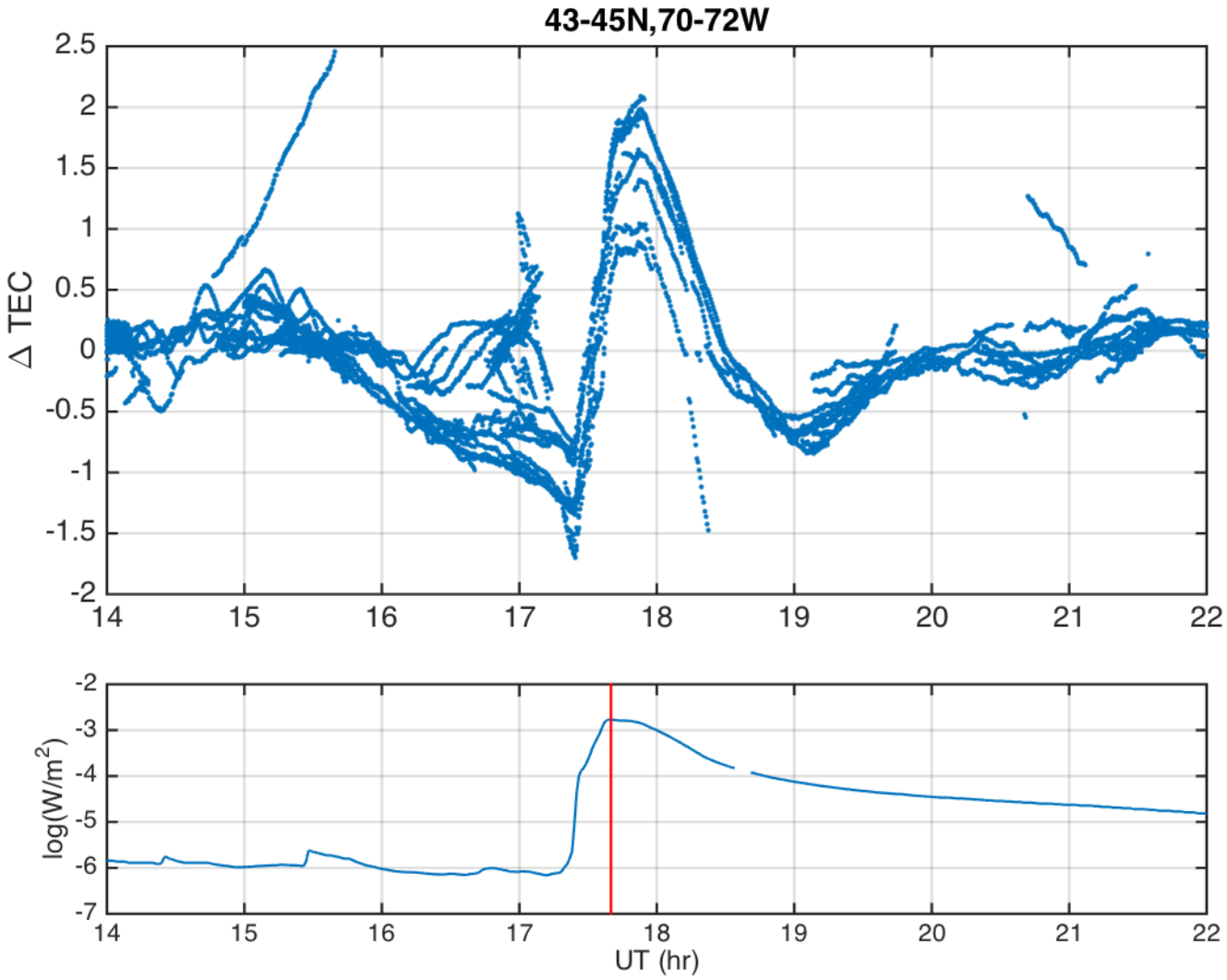
# dTEC over two hemispheres



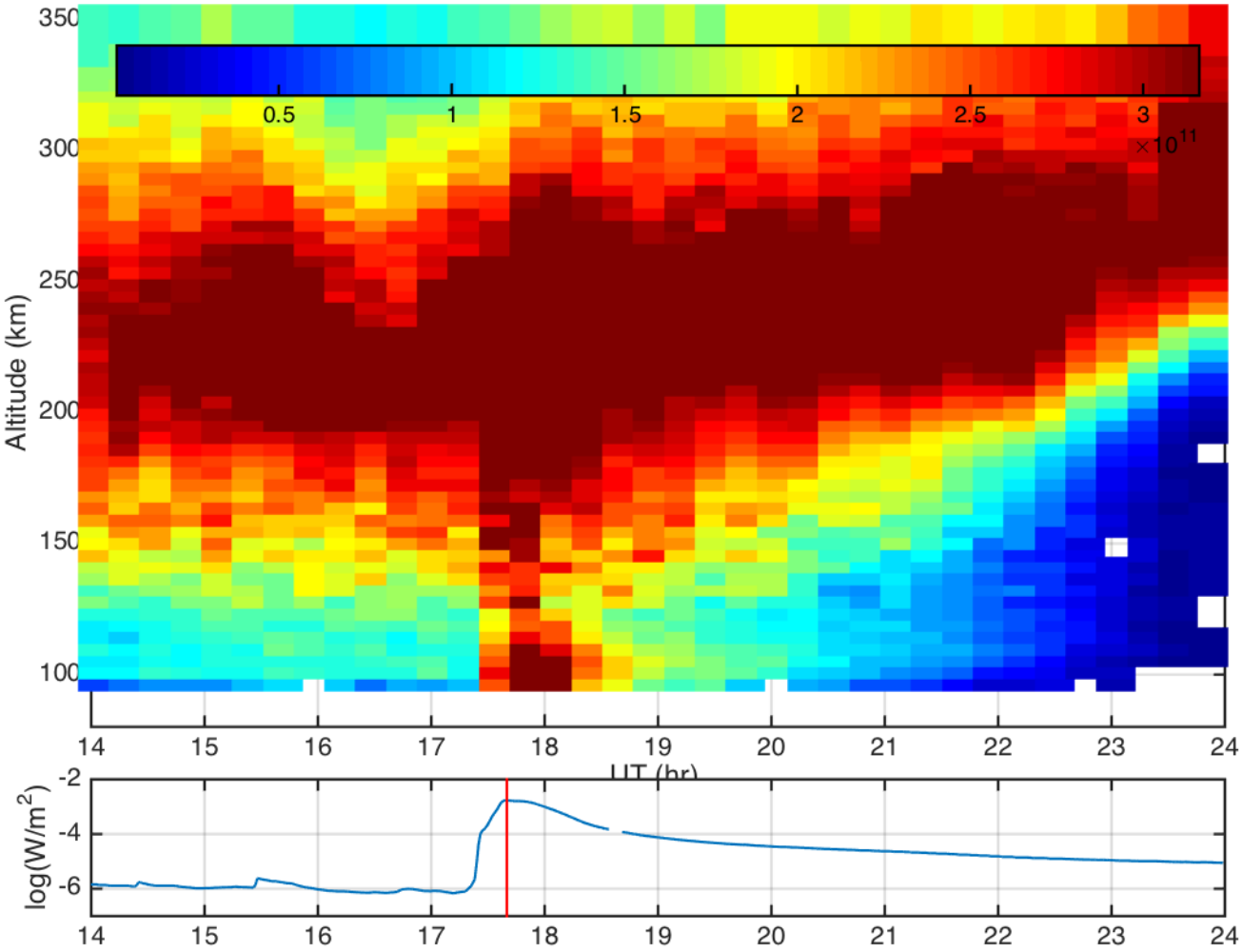
# dTEC in the Northeast US



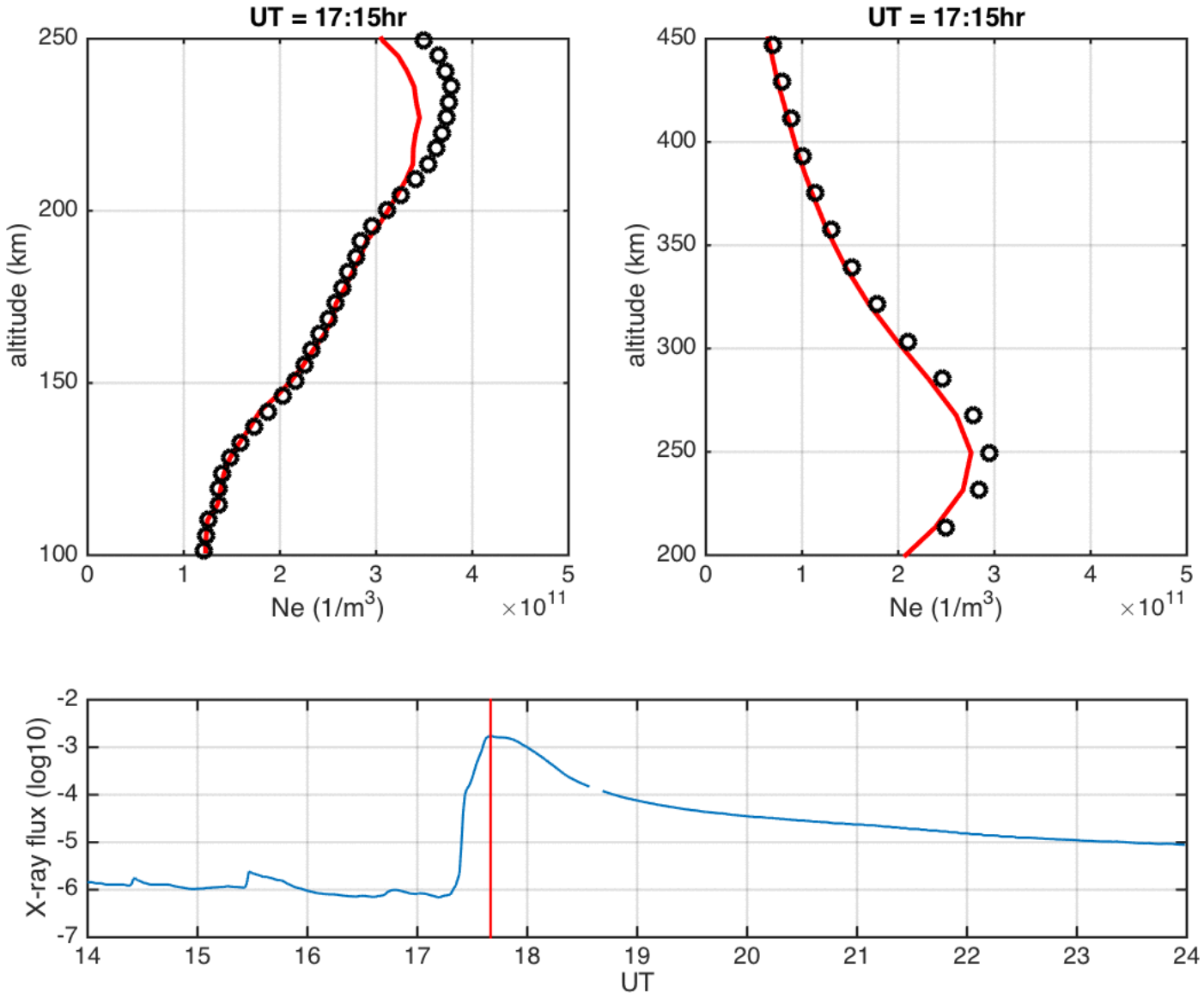
# dTEC near Millstone Hill ISR



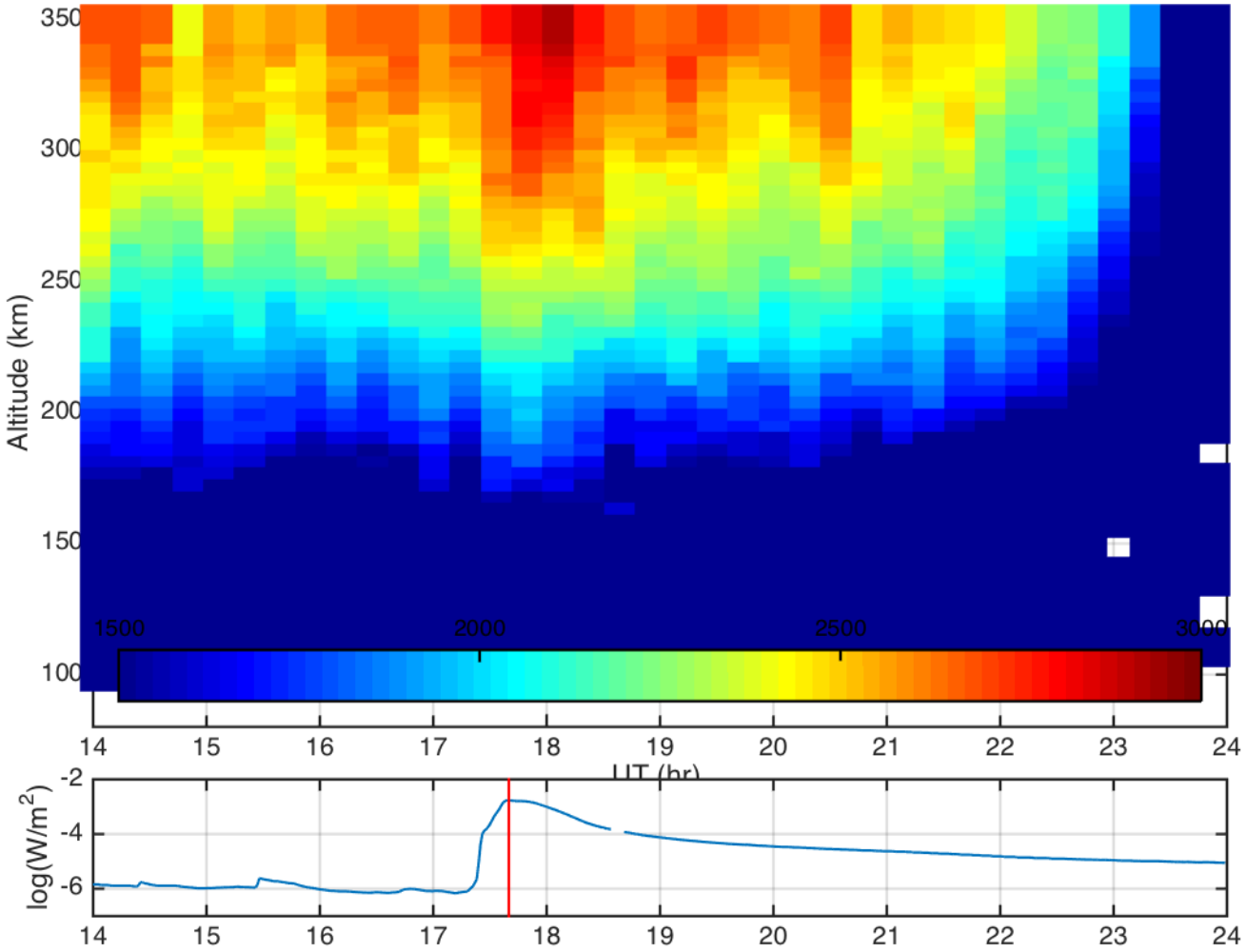
# Millstone Hill ISR: Ne



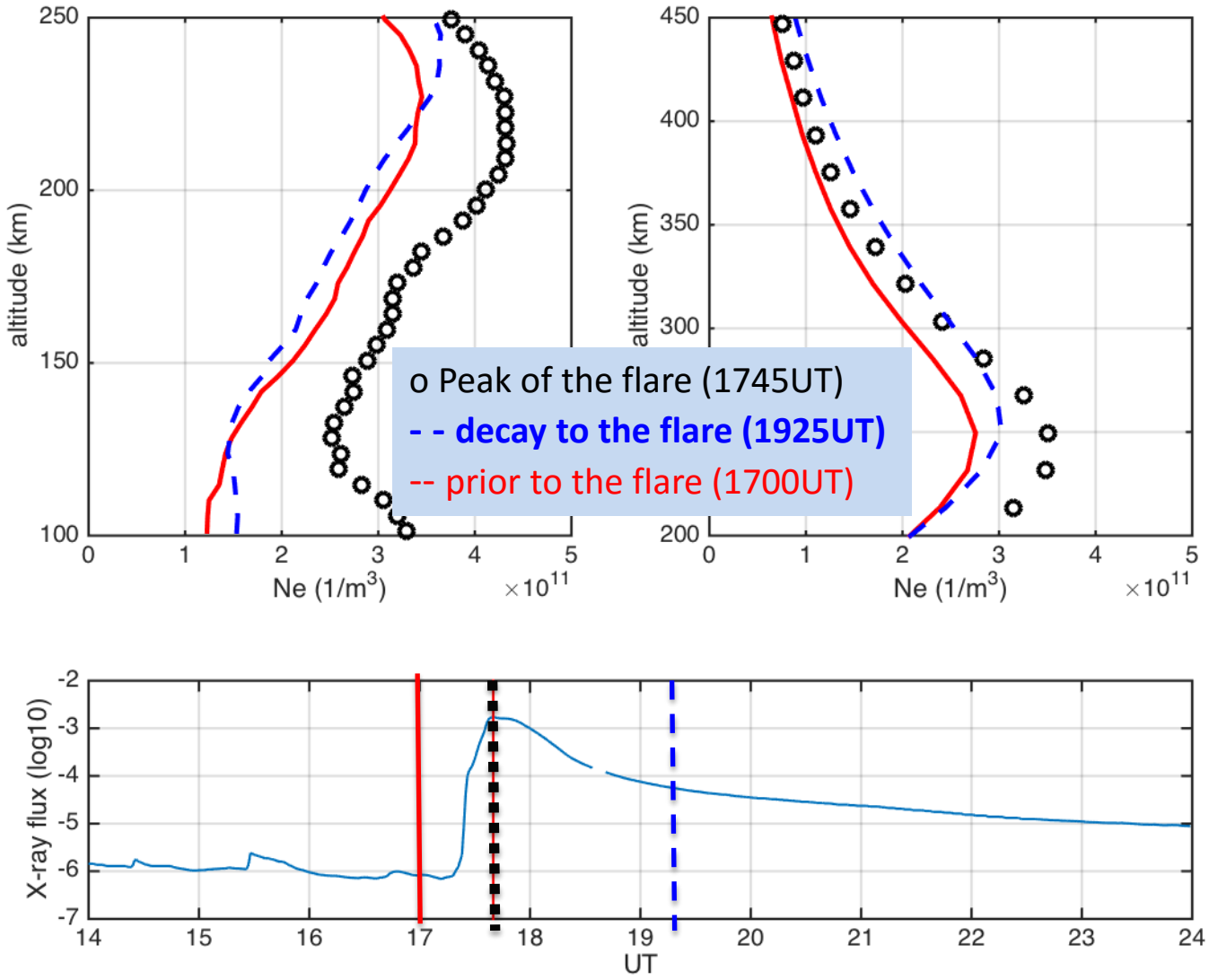
# Millstone Hill ISR: Ne



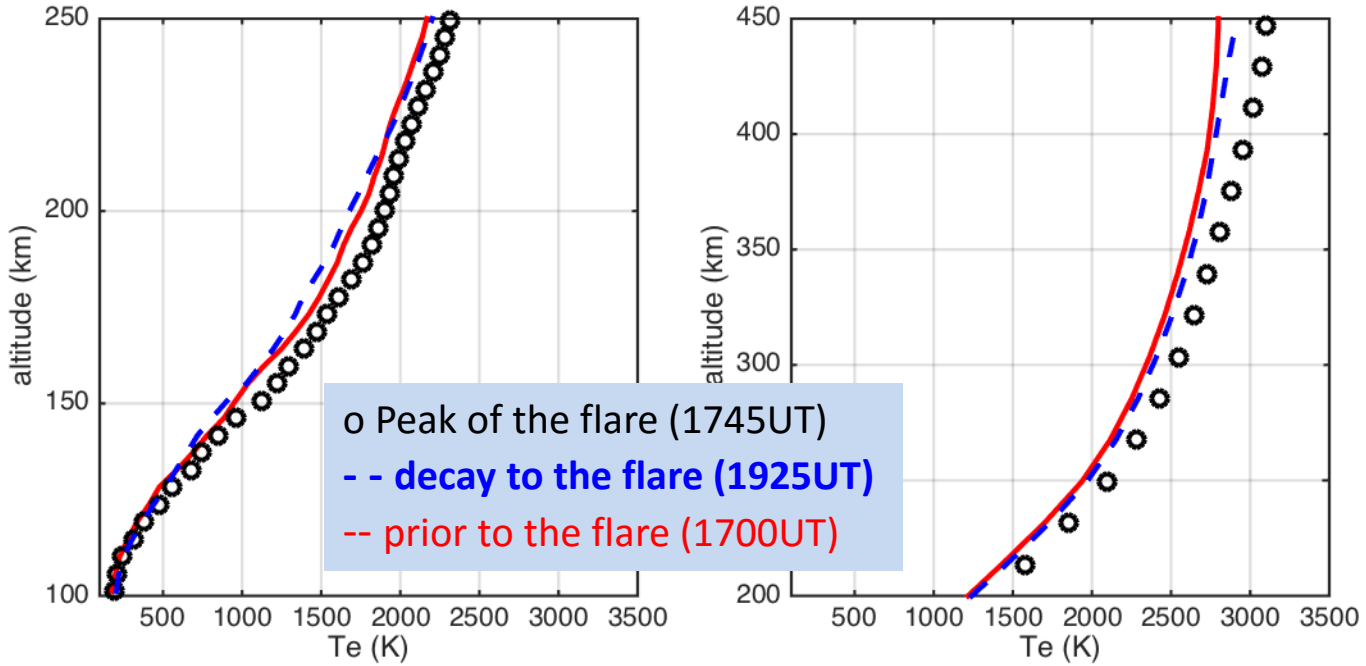
# Millstone Hill ISR: Te

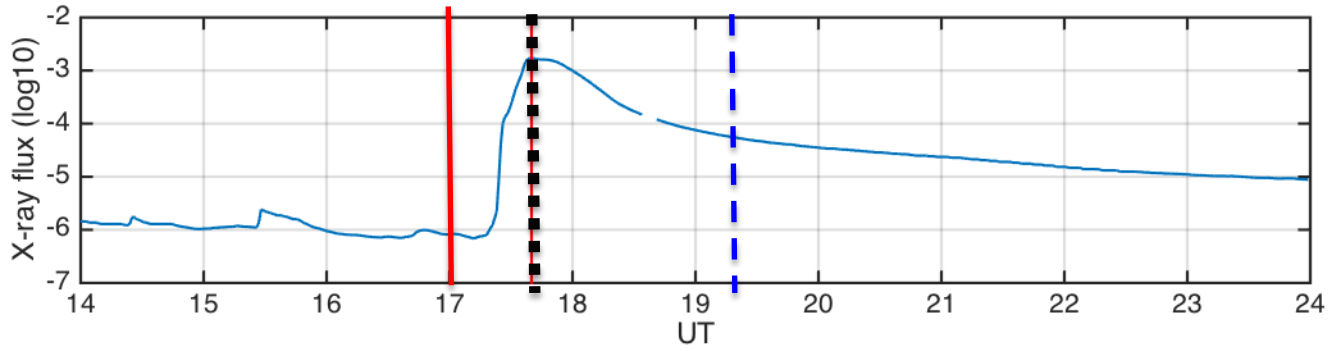


# Millstone Hill ISR: Ne



# Millstone Hill ISR: Te

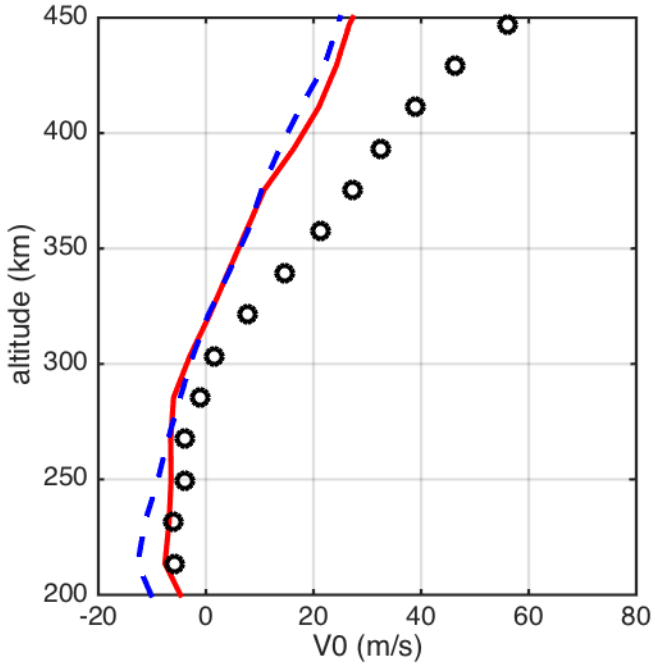


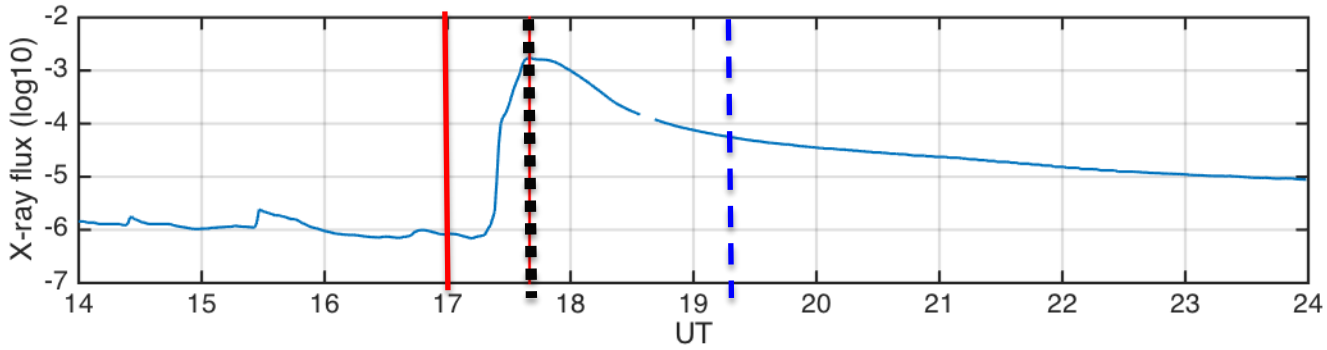



# Millstone Hill ISR: Vo

F region
- more upward drifts following the flare

o Peak of the flare (1745UT)
**- - decay to the flare (1925UT)**
-- prior to the flare (1700UT)



# Summary

- High res TEC data over North America allows for determination of a large scale TID following the peak of X11 solar flare
- Simultaneous onset of TEC enhancements; but decay of the TEC enhancement clearly latitude and hemisphere dependent
- E and F region electron density are significant, both contributing to TEC
- Flare caused photoelectron heating
- Flare caused upward ion drift (diffusion?) in the F region