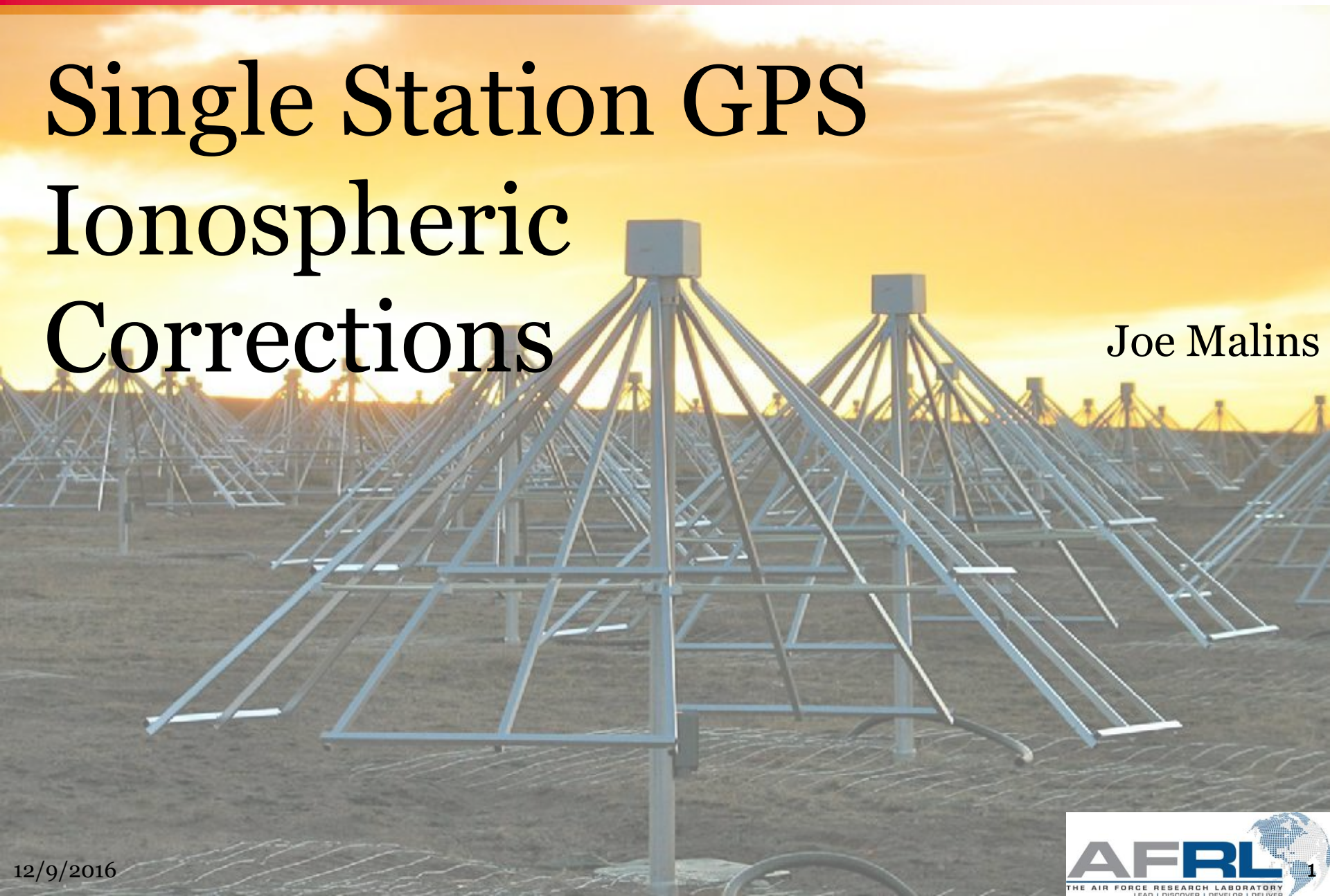
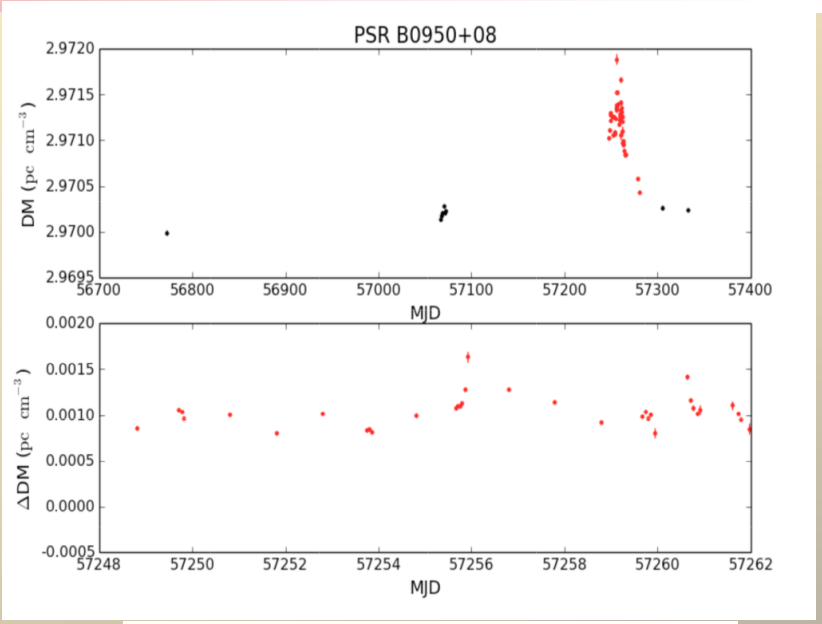
Single Station GPS Ionospheric Corrections

Joe Malins

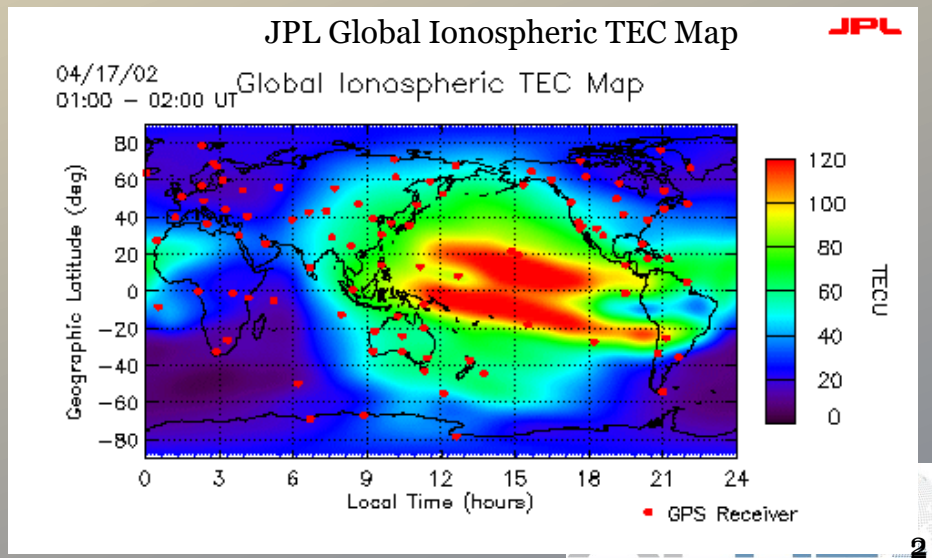


Statement of Problem

- Want Faraday rotation to measure magnetic field of sun and CMEs
- Currently: IONEX Files:
  - use global models involving hundreds of GPS stations
- Problem: not many GPS receivers located near LWA
- Problem: Global models update approximately every hour.
  - Time of Appreciable Change ~10 min



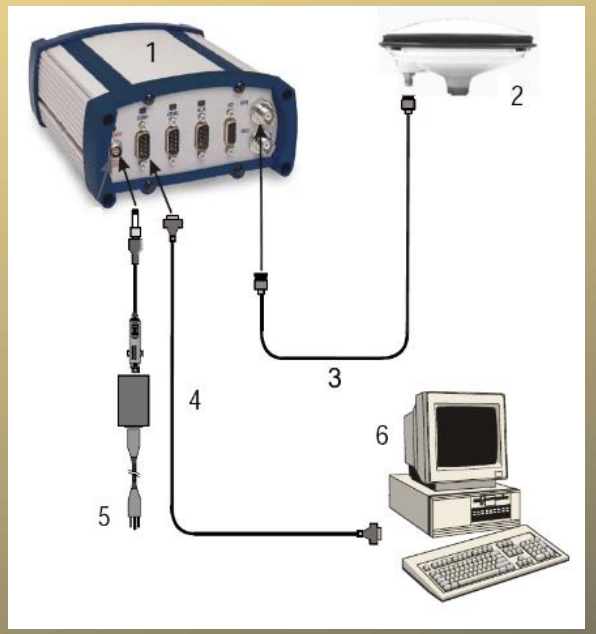
Stovall, Kevin (UNM)



Equipment

LWA

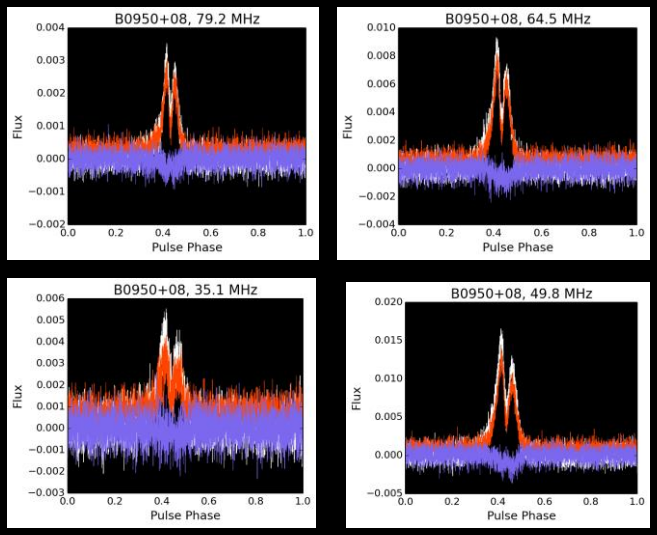
Dual Frequency GPS Antenna



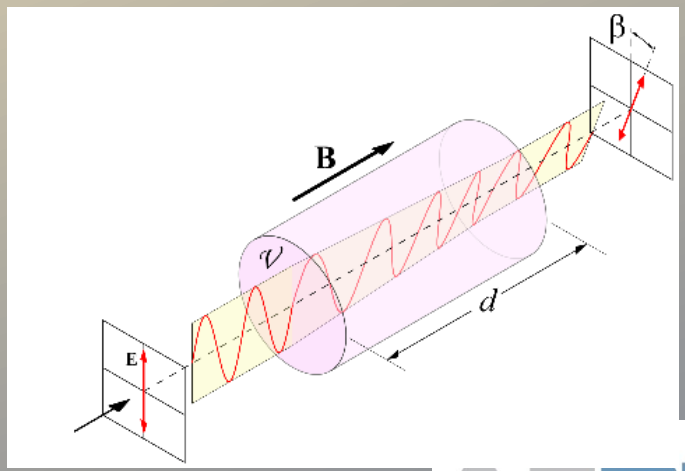
- NovAtel 4004B Dual Frequency GPS
- Borrowed from Air Force Research Lab Scintillation Network Decision Aid (SCINDA) program
- Self-biasing, 10s resolution, Plasmasphere correction

RM measurement

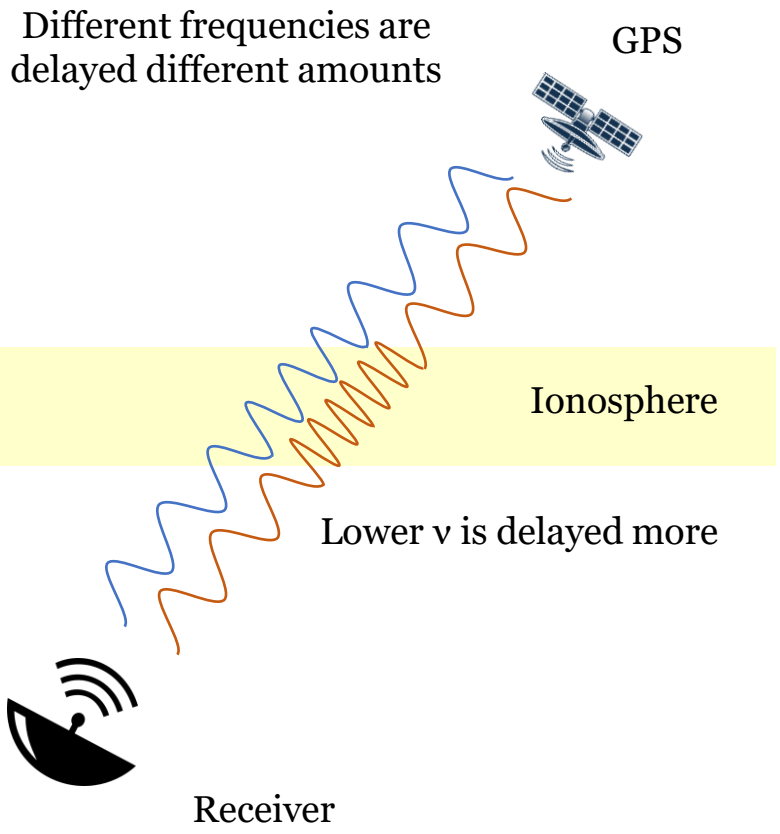
- Using Polarized Pulsars
- Three contributions to rotation measure:
  - Material surrounding pulsar
  - Interstellar/Interplanetary Medium
  - Ionosphere and near earth plasma
- Assume near constant ISM and material surrounding pulsar
  - or at least changing on long time scales
- At large sun angles Short time scale change only due to ionosphere
- Find rotation measure, measure ionospheric contribution, fit RM curve to ionosphere



See Veronica Dike (UNM) Poster



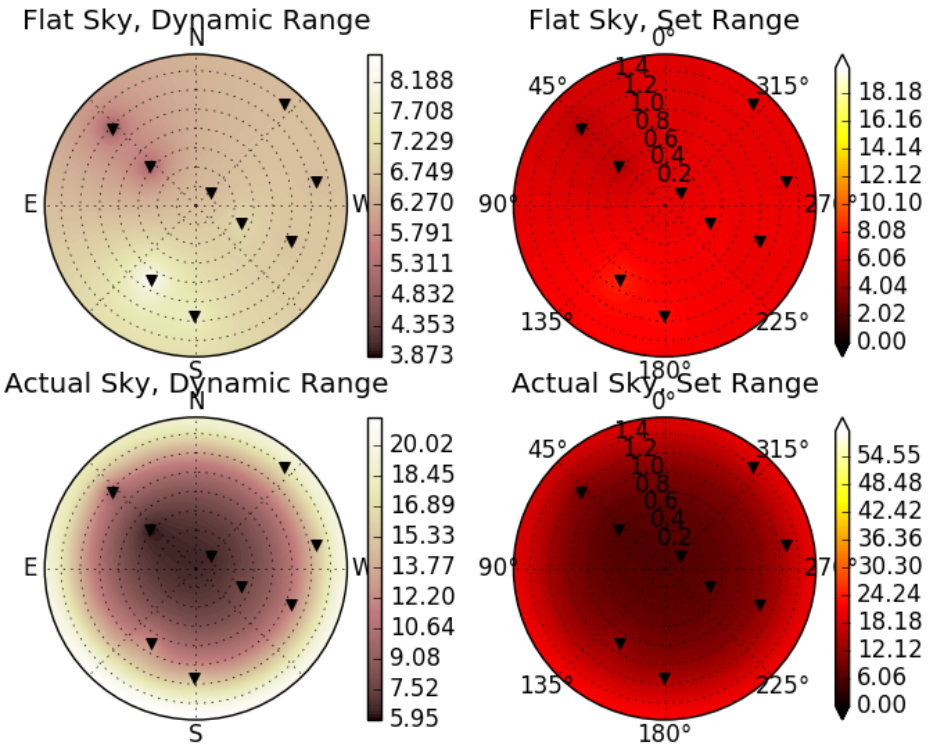
Ionosphere Measurement



- Dual Frequency: 1575.42 MHz and 1227.60 MHz
- Ionosphere is plasma
- Plasmas causes group velocity delay, phase velocity increase in EM waves
- Delays are strongly frequency dependent
- Integrated electron density: Total Electron Content (TEC)
- Measured in n_e/m^2 or TEC units (TECU) 1 TECU = 10^{16} n_e/m^2
- No profile information

Better Corrections

Interpolated Observation at LWA1
at 2016/10/14 12:00:00 UTC

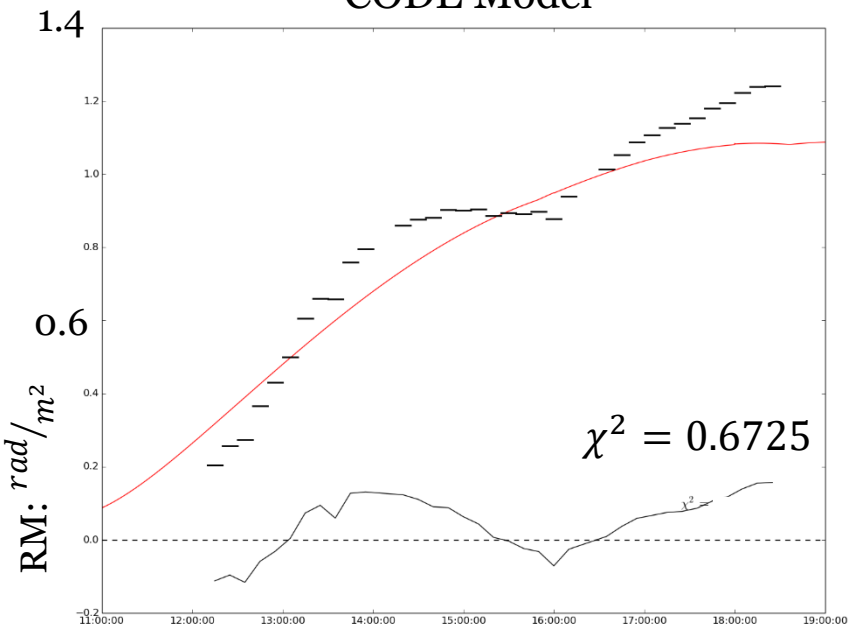


- Each satellite provides accurate data to a single point on the sky
- Between 7-14 satellites at any given time
- For points between satellites, use linear weighted average of satellites

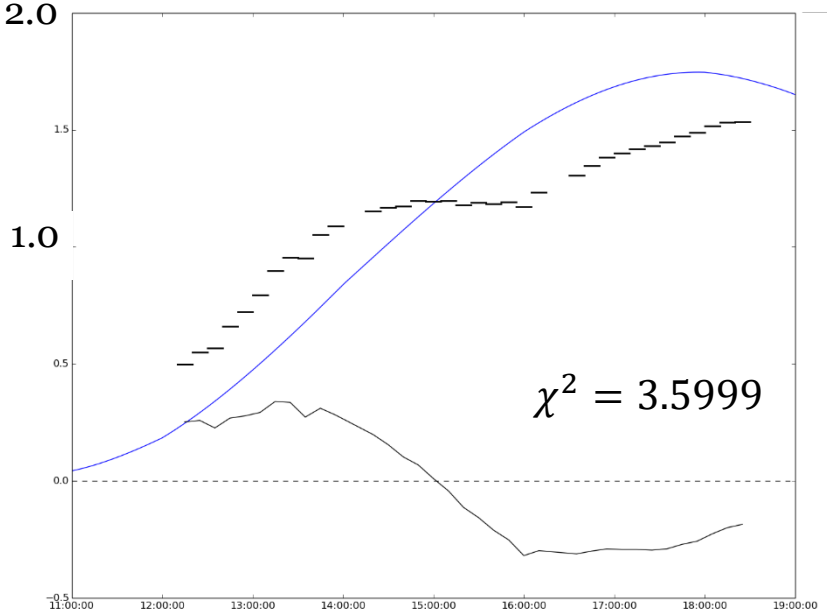
$$TEC = \sum \frac{\rho}{d_l} TEC_1$$

$$\rho = \frac{1}{\sum \frac{1}{d_l}}$$

CODE Model



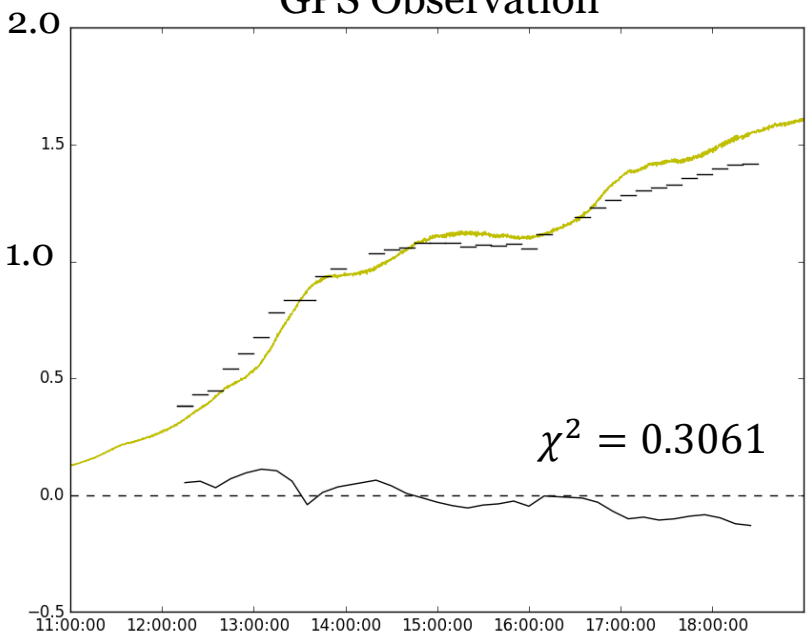
JPL Model



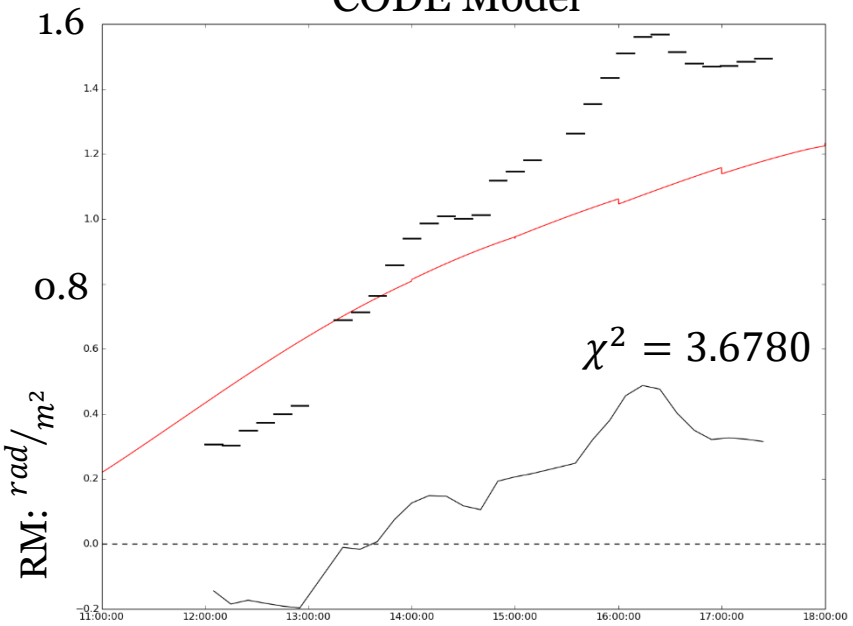
Pulsar: B0950+08
3x 2Hour Observations
(Black Dashed Lines)

Date: 2016/09/23

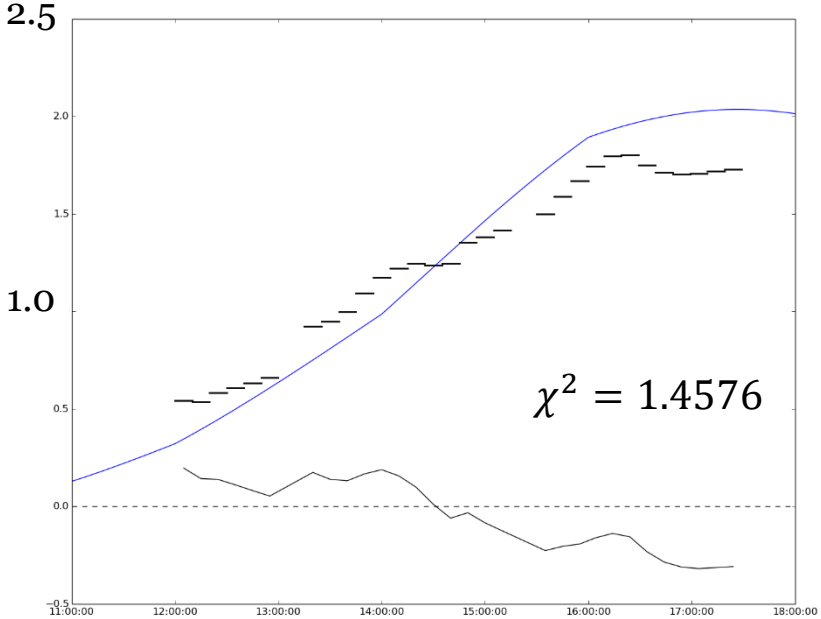
GPS Observation



CODE Model



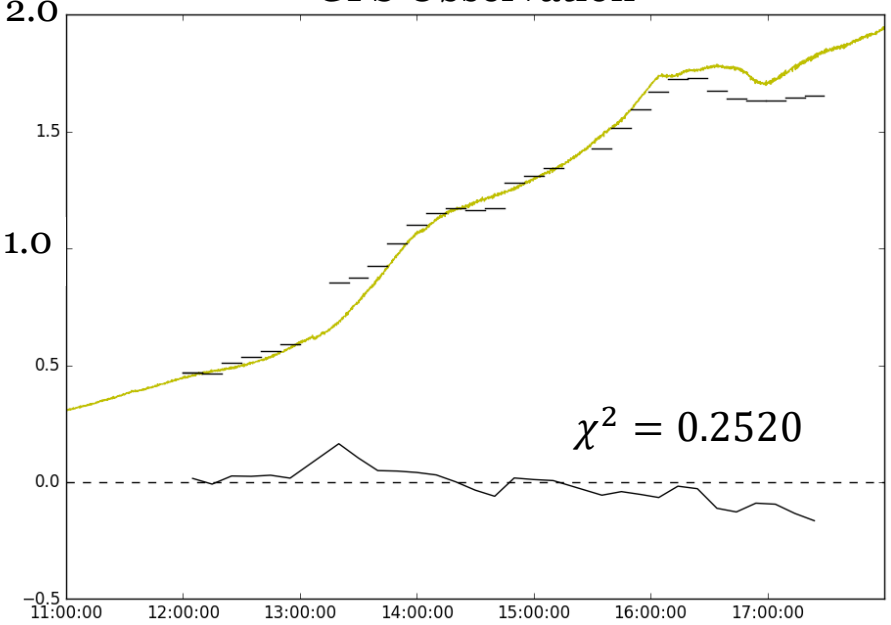
JPL Model



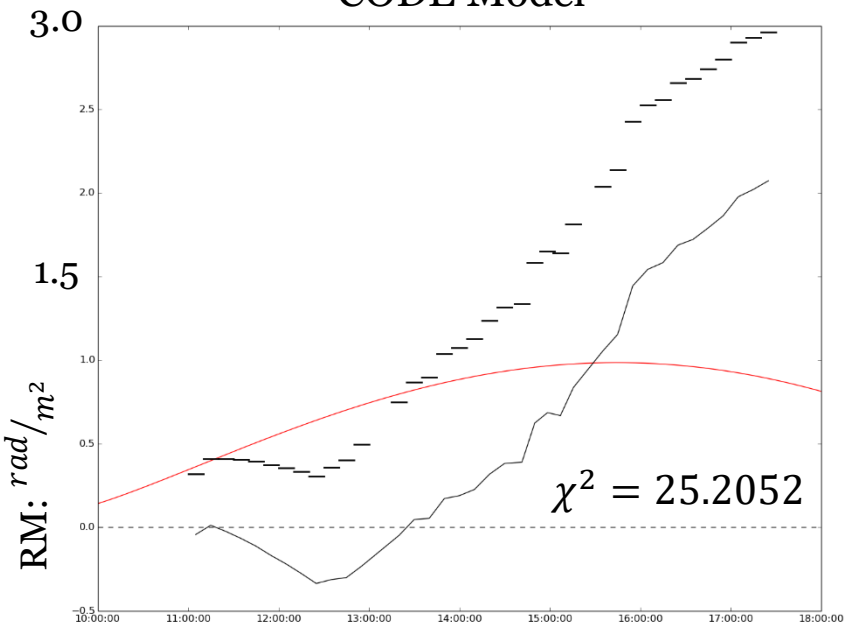
Pulsar: B0950+08
3x 2Hour Observations
(Black Dashed Lines)

Date: 2016/10/05

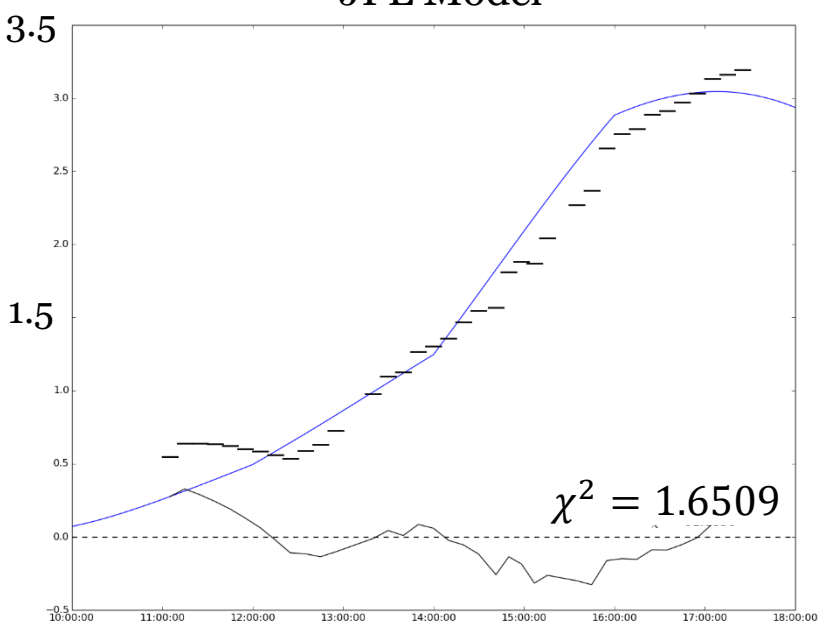
GPS Observation



CODE Model



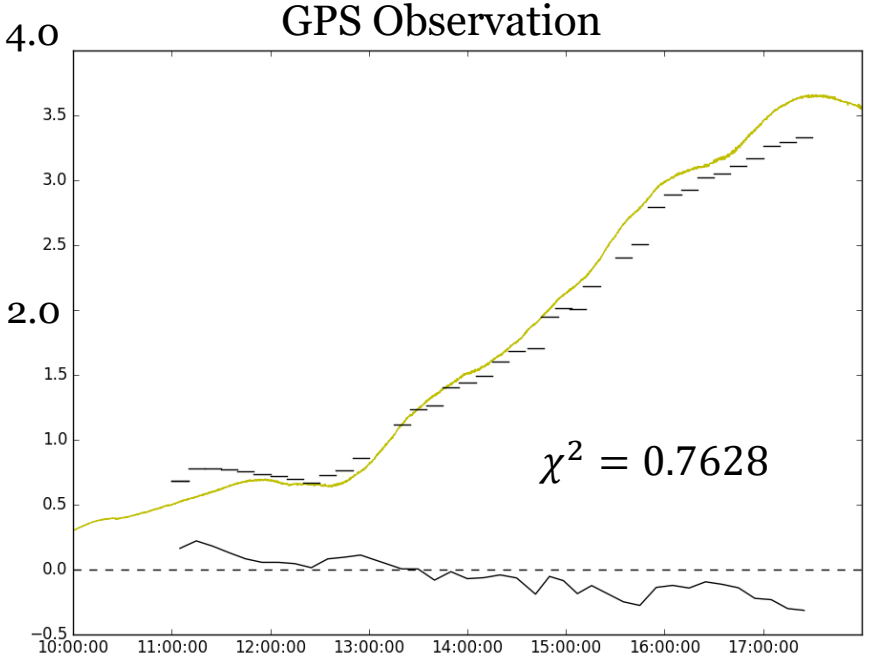
JPL Model



Pulsar: B0950+08
3x 2Hour Observations
(Black Dashed Lines)

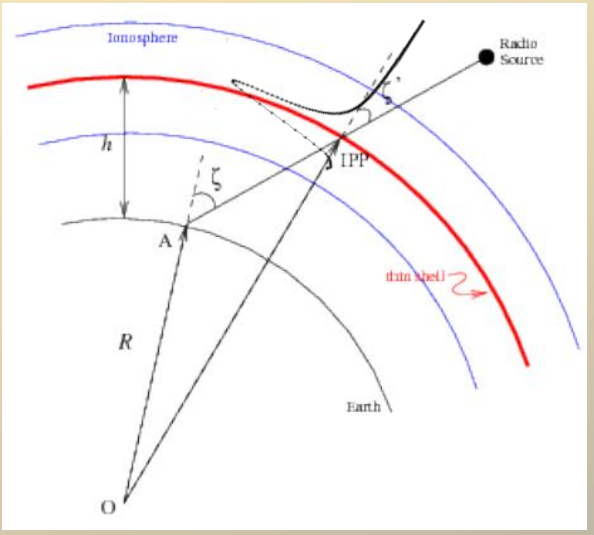
Date: 2016/10/14

GPS Observation

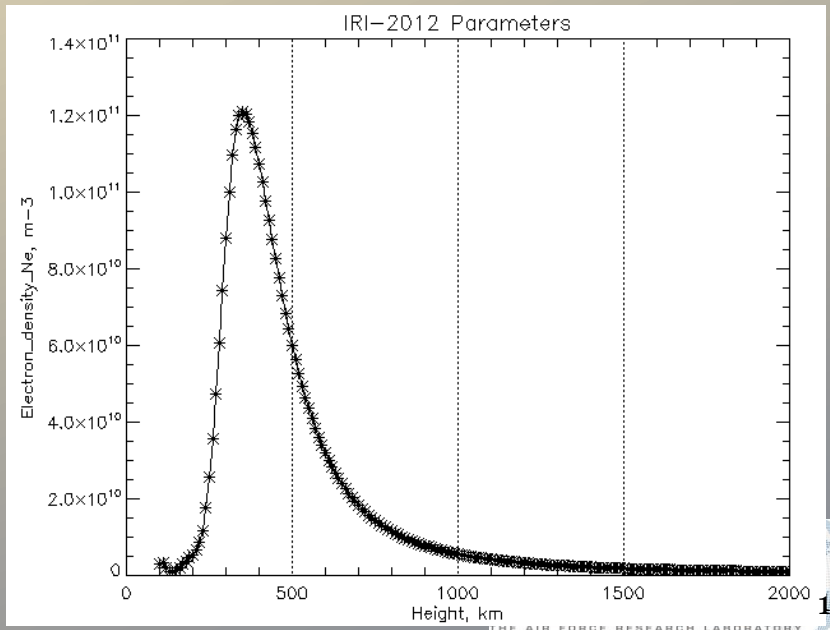


Height Dependence

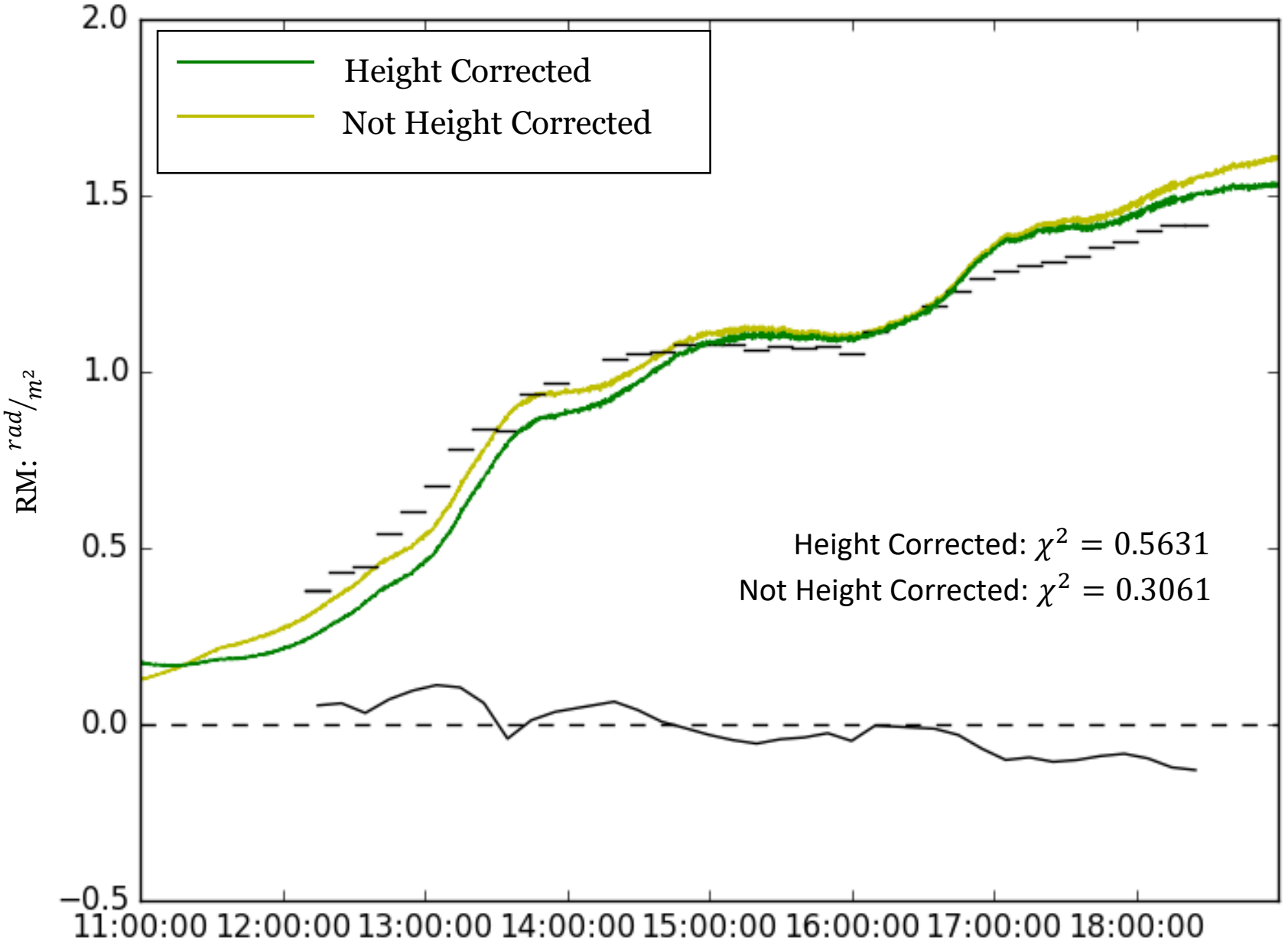
- Current model : Thin Shell Model
- Attempt electrons distributed along profile
- 1st Try:
  - 191 points along International Reference Ionosphere (IRI)
- 2nd Try:
  - AFRL Ionosonde data from AFRL at Kirtland



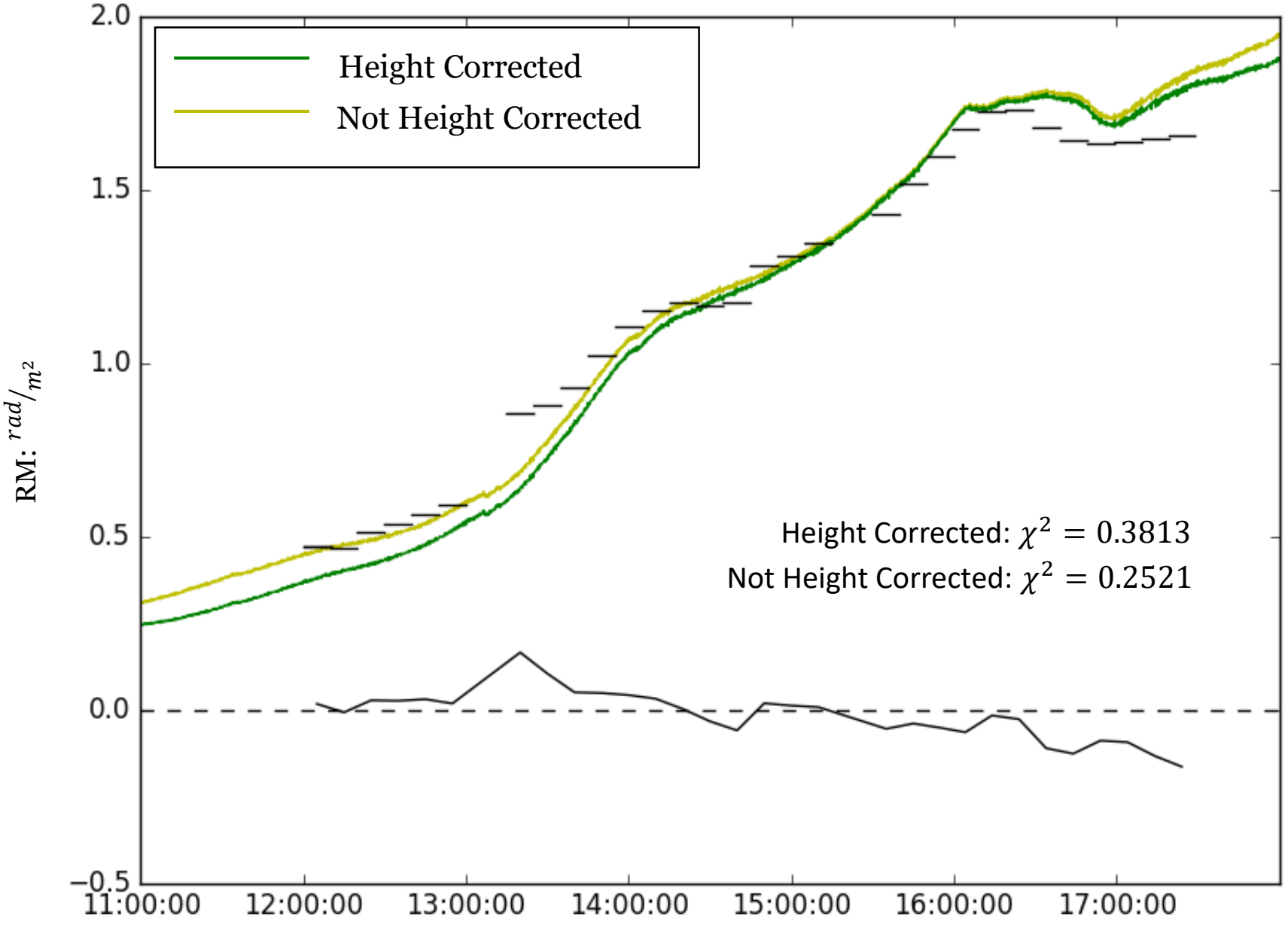
C. Sotomayor-Beltran et al.: Ionospheric Faraday rotation



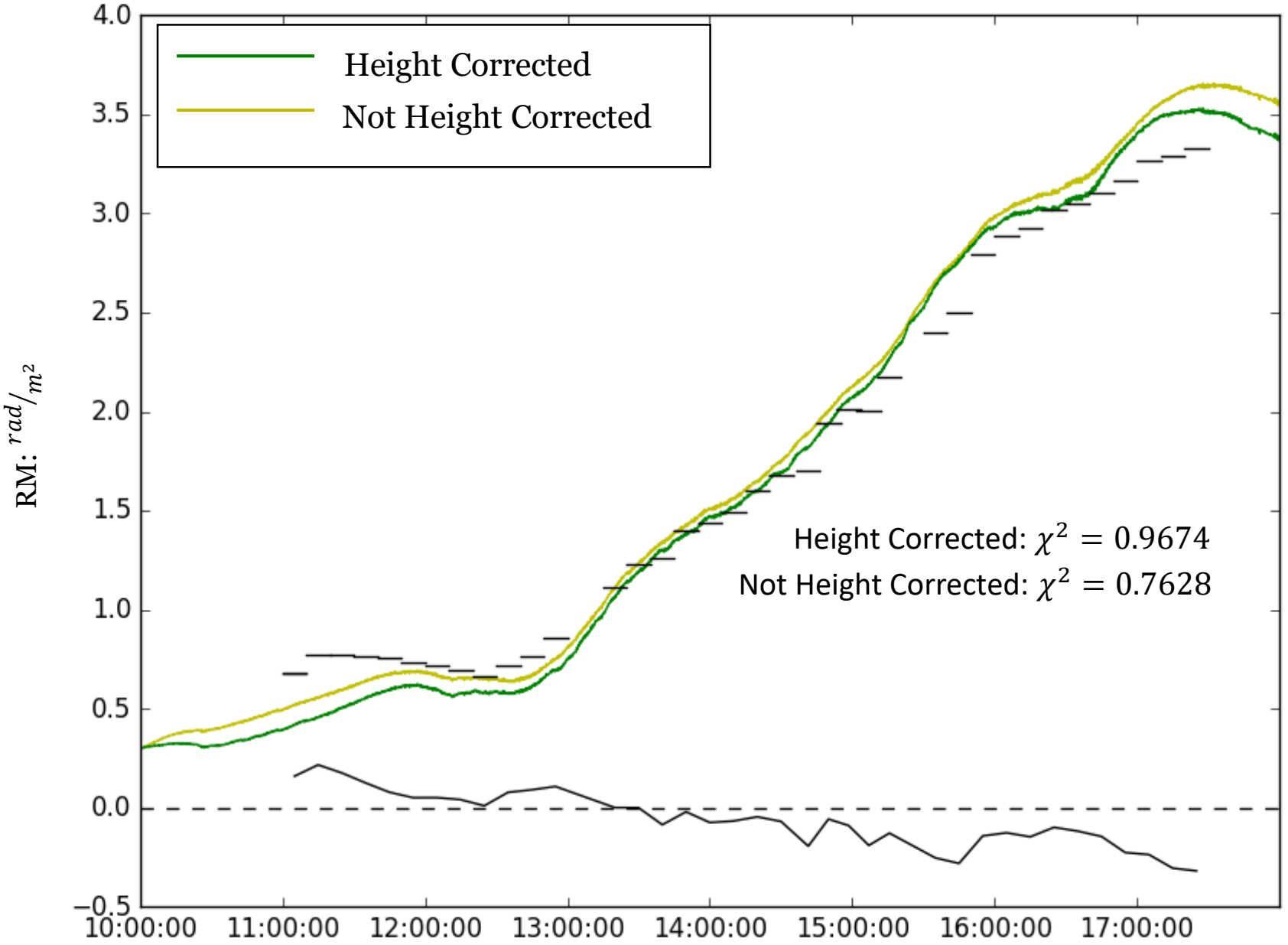
2016/09/23


Height Corrected
Not Height Corrected
Height Corrected: $\chi^2 = 0.5631$
Not Height Corrected: $\chi^2 = 0.3061$
RM: rad/m^2
2.0
1.5
1.0
0.5
0.0
−0.5
11:00:00
12:00:00
13:00:00
14:00:00
15:00:00
16:00:00
17:00:00
18:00:00

2016/10/05


Height Corrected
Not Height Corrected
RM: rad/m^2
2.0
1.5
1.0
0.5
0.0
−0.5
11:00:00
12:00:00
13:00:00
14:00:00
15:00:00
16:00:00
17:00:00
Height Corrected: $\chi^2 = 0.3813$
Not Height Corrected: $\chi^2 = 0.2521$

2016/10/14


Height Corrected
Not Height Corrected
Height Corrected: $\chi^2 = 0.9674$
Not Height Corrected: $\chi^2 = 0.7628$
RM: rad/m^2
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
10:00:00
11:00:00
12:00:00
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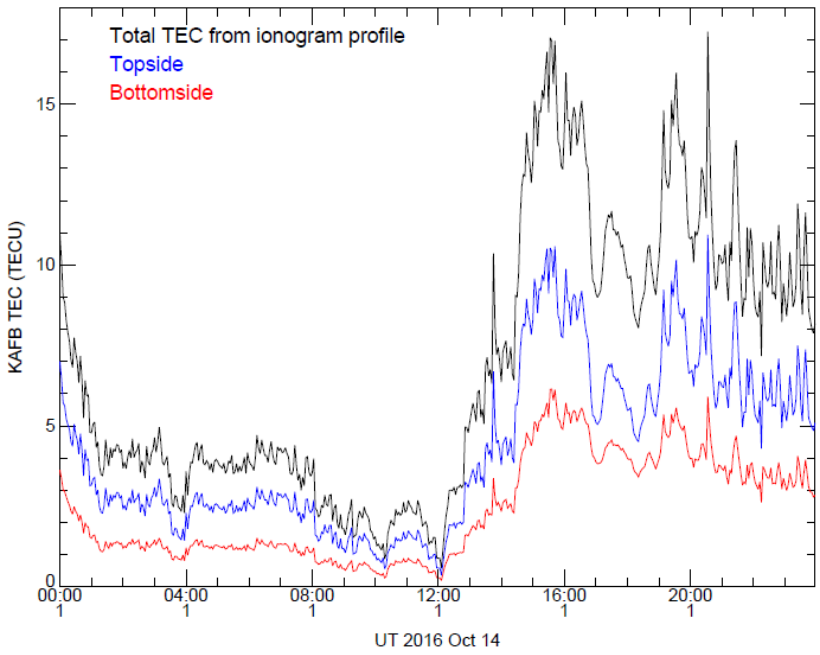
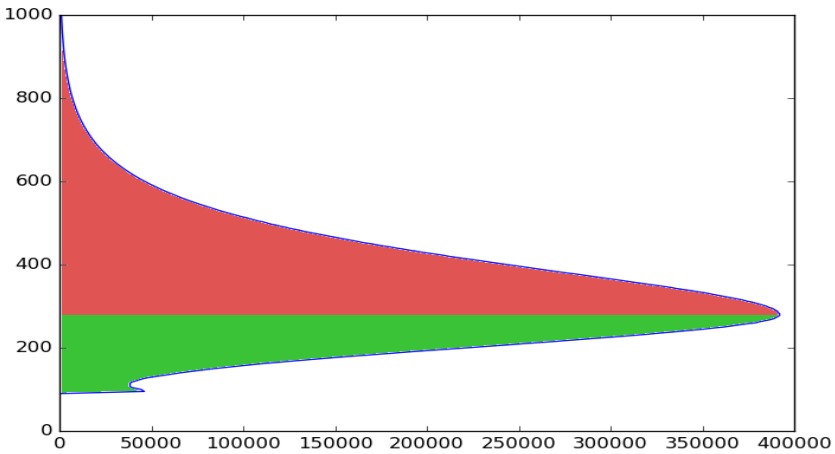
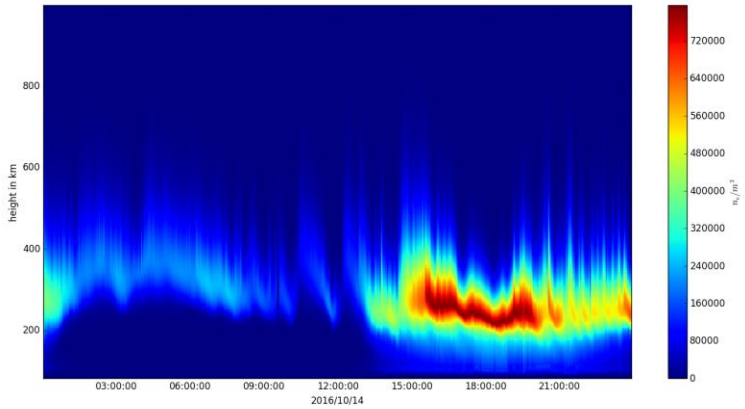
15:00:00
16:00:00
17:00:00







$$\frac{N(h)}{N_m} = [S(h)]^{-1/2} \exp\{\frac{1}{2}[1 - Y - \exp(Y)]\}$$

$$Y = \frac{1}{h_m}\int_{h_m}^{h} \frac{dh}{S(h)}$$

$$\frac{1}{S(h)} = \frac{1}{S_1(h)} + \frac{1}{S_2(h)}$$

$$S_1(h) = c_1\left[\operatorname{sech}^2\left(\frac{{}^{h}/_{h_m} - 1}{\frac{\beta}{h_m}}\right)\right]^{-1}$$

$$S_2(h) = c_2\frac{\left[1 + \left({}^{h}/_{h_m}\right)^2\right]^{\alpha}}{{}^{h}/_{h_m}}$$

NSUMEI ET AL.: NEW VARY-CHAP TOPSIDE PROFILE (2012)

Data from Stephen White AFRL

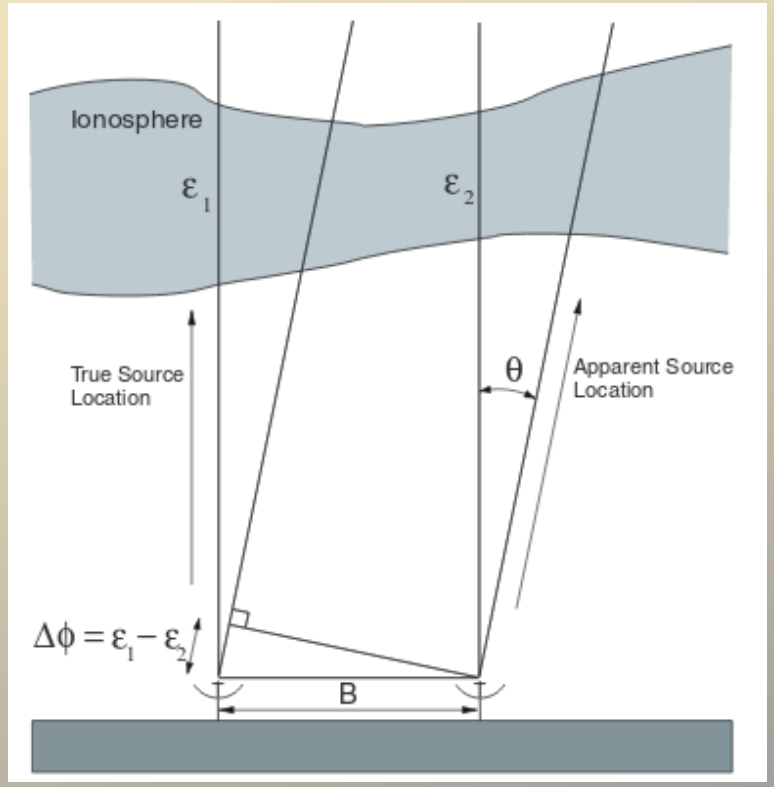
What's happening

Several Options

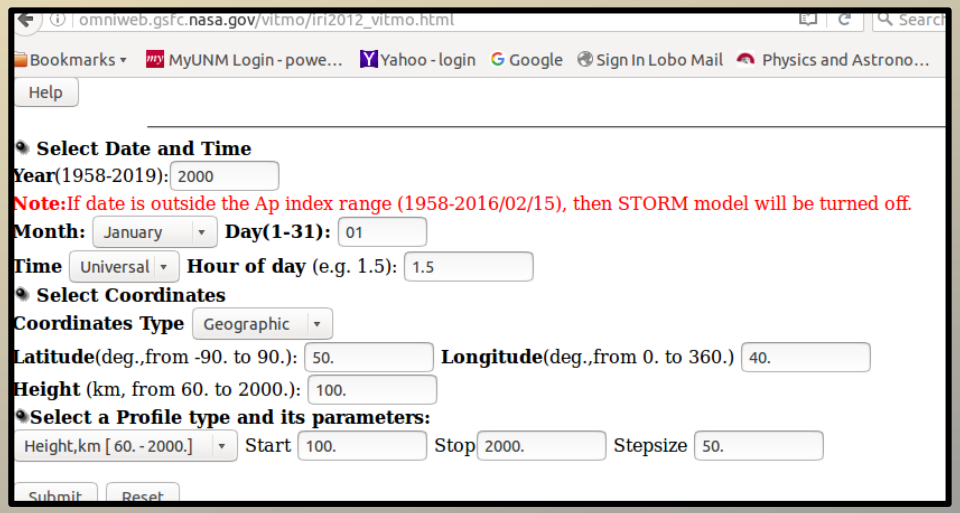
- IGRF12 is not reporting accurate Magnetic Field
  - Seems unlikely due to stability of magnetic field
- TEC from GPS in inaccurate
  - TEC compares very well to other GPS in area
  - Very similar to SCINDA GPS at Sevilleta
- Profile is in accurate
  - Profile is more concentrated around Ionosphere F layer

Near Term Plans

- Continue to use GPS to calibrate data for low frequency observations
- Eventually, want to use GPS Corrections for correlating LWA1 and LWA Sevilleta
- Can provide data universally for interested parties for VLA corrections
  - ➢ Updated JPL IONEX files with GPS overlay and 1min time resolution



COHEN & ŘOTTGERING



Shao, X.-M., and E. H. Lay (2016)