High-latitude F-Region Irregularities: Even the ionosphere gets a day off.

Ahmed Said Eltrass (Virginia Tech)
Pratik Prasad Joshi (Virginia Tech)
Marcos Inonan Moran (JRO)
Alexandre Tardelli (Univap)
Maik Wolleben (Univ. Calgary)
Matt Young (Boston Univ)

Why do people code radar pulses ?

What are some of the common codes used in ISR processing and what are they used for ?

Why do people "code" radar pulses?

- The use of codes allows for the reduction of pulse power required to transmit signals while also obtaining the increased range resolution.
- A pulse compression radar is a practical implementation of a matched-filter system. The coded signal may be represented either as a frequency response or as an impulse time response of a coding filter.

What are some of the common codes used in ISR processing and what are they used for?

The choice of a code is dependent upon the type of waveform, and also the method of generation and processing.

Some widely used radar codes:

- Barker codes
- Complementary codes

Pulse code

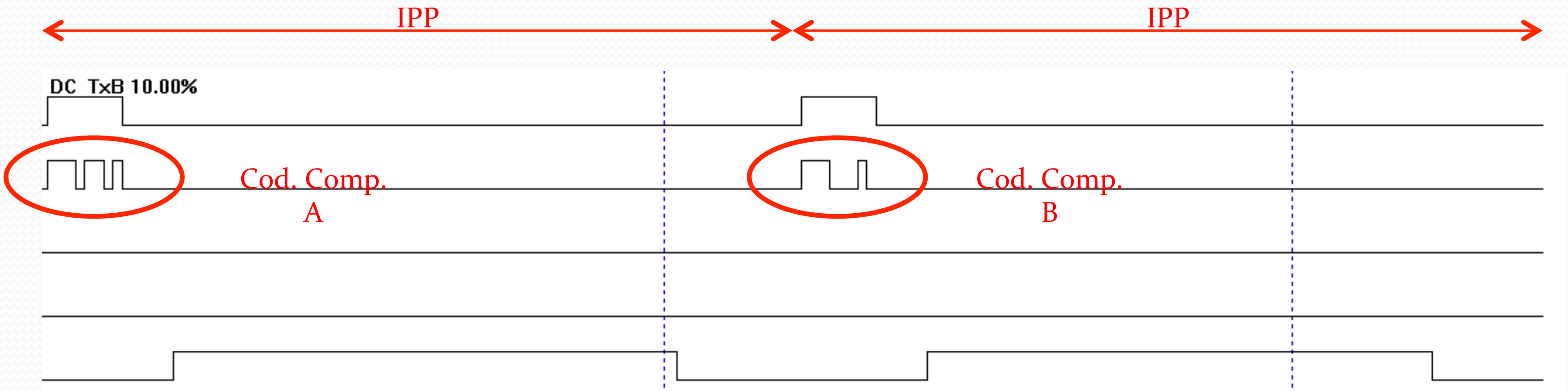
Is it possible to remove the side lobes?

- *Complementary sequences*

$$R_x(k) = \sum_{j=0}^{N-k-1} x_j x_{j+k}.$$

$$R_a(k) + R_b(k) = 0,$$

Is it possible to remove the side lobes?



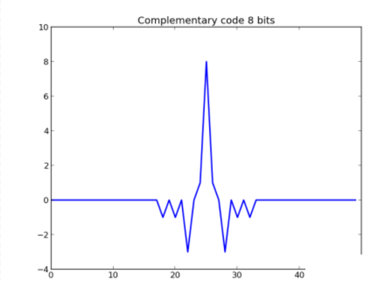
IPP

IPP

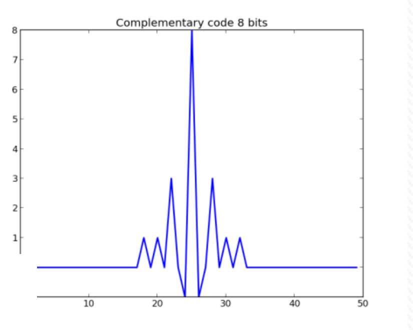
DC TxB 10.00%

Cod. Comp.
A

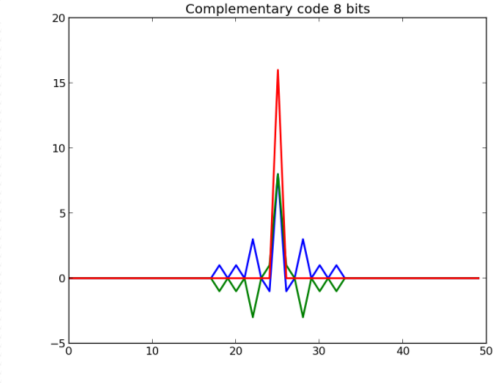
Cod. Comp.
B



Complementary code 8 bits



Complementary code 8 bits



Complementary code 8 bits

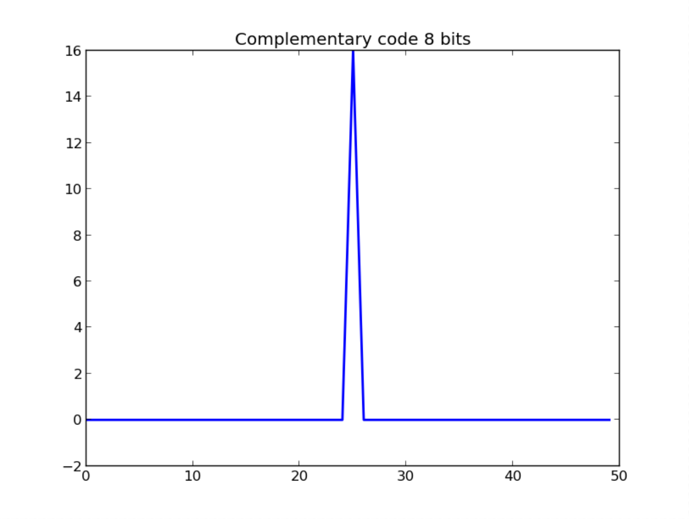
How to create a Complementary Code

Cod. Comp. A	11	11 10	1110 1101
Cod. Comp. B	10	11 01	1110 0010
	Codigo Comp 2bits	Codigo Comp 4bits	Codigo Comp 8bits

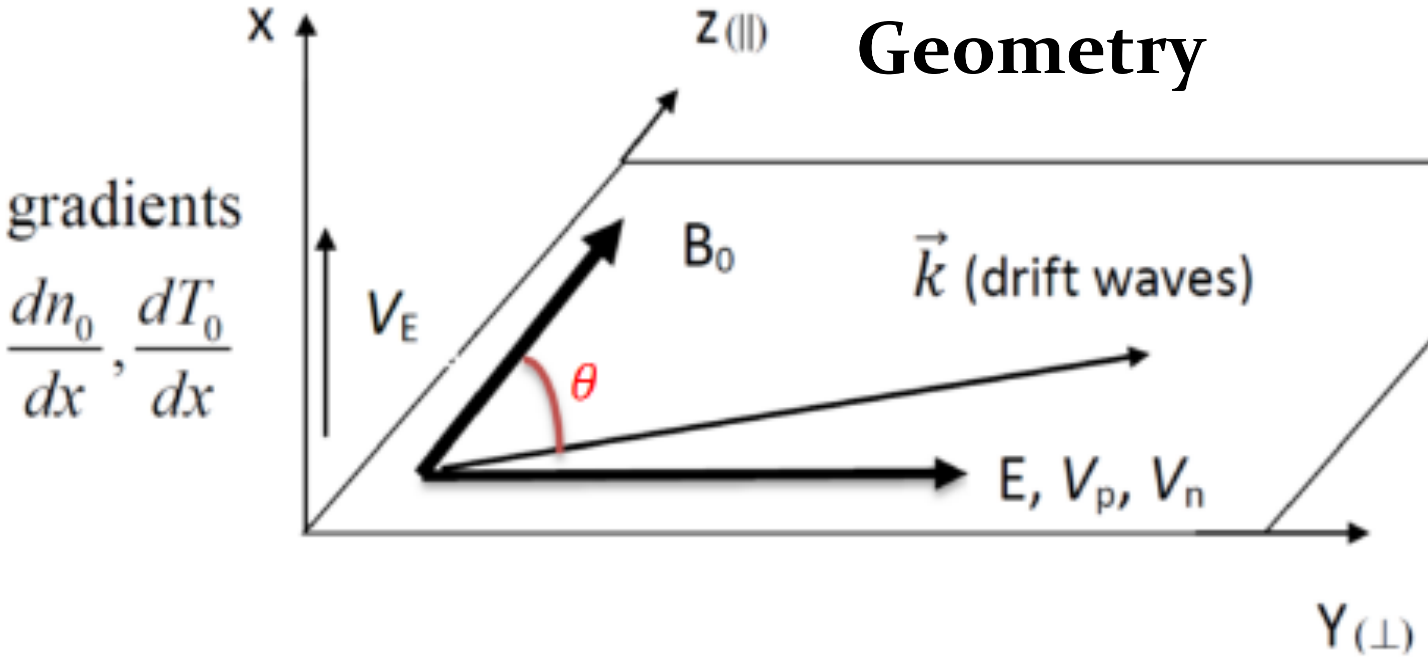
Drawbacks

Susceptible to the movement of the target

Sometimes no cancelation



Science



The TGI geometric relationship relative to the magnetic field, the temperature gradient, the density gradient, and the wave vector of resistive drift waves. This geometry is also used for GDI driven by diamagnetic and Pederson drifts.

Linear kinetic theory of TGI

The zeroth order equilibrium velocity distribution function incorporates density gradients, temperature gradients, and temperature anisotropy . It is taken to be [Miyamoto, 1978]:

$$f_0(x, v_\perp, v_\mathrm{P}) = \frac{n_0}{(2\pi v_{t\perp}^2)(2\pi v_{t\mathrm{P}}^2)^{1/2}}\left[1+\left(-\kappa_n+\delta_{T\perp}\frac{v_\perp^2}{2v_{t\perp}^2}+\delta_{T\mathrm{P}}\frac{v_\mathrm{P}^2}{2v_{t\mathrm{P}}^2}\right)\left(x-\frac{v_y}{\Omega}\right)\right]\exp\left(-\frac{v_\perp^2}{2v_{t\perp}^2}-\frac{v_\mathrm{P}^2}{2v_{t\mathrm{P}}^2}\right)$$

The kinetic electrostatic dispersion relation is developed to calculate the TGI with: full kinetic effects for landau damping , finite gyro-radius effects , temperature anisotropy , and electron Collisional Effects

$$k_\perp^2+k_\mathrm{P}^2+\sum_j \omega_{pj}^2\left\{\frac{m_j}{T_{\perp j}}+I_0(b_j)e^{-b_j}\left(\frac{m_j}{T_{\mathrm{P}j}}-\frac{m_j}{T_{\perp j}}\right)+\frac{\delta_{T\mathrm{P}j}(\omega+i\nu_j)}{2k_\mathrm{P}^2(T_{\mathrm{P}j}/m_j)}\frac{k_\perp}{\Omega_j}I_0(b_j)e^{-b_j}(1+\zeta_{0j}Z(\zeta_{0j}))+I_0(b_j)e^{-b_j}\zeta_{0j}Z(\zeta_{0j})\left(\frac{m_j}{T_{\mathrm{P}j}}+\frac{k_\perp}{(\omega+i\nu_j)\Omega_j}\left(-\kappa_j+(f_{0j}-1)\delta_{T\perp j}-\frac{\delta_{T\mathrm{P}j}}{2}\right)\right)\right\}\Big/$$

$$\left\{1+\frac{i\nu_j}{\omega+i\nu_j}I_0e^{-b_j}\zeta_{0j}Z(\zeta_{0j})\right\}=0$$

- A numerical solver used for this dispersion relation will allow study of the TGI over a wide range of parameter regimes.

Linear kinetic theory of GDI

- The zeroth order equilibrium velocity distribution function incorporates collisional effects , density gradients , and $E \times B$ drift velocity. It is taken to be [Gary and Cole, 1983]:

$$f_0(x,v) = \frac{n_0}{(2\pi v_t^2)^{3/2}}\left[1+\kappa_n\left(x+\frac{v_y}{\Omega}-\nu\frac{v_x}{\Omega^2}\right)+\frac{v_E}{v_t}\left(\frac{v_x}{v_t}+\nu\frac{v_y}{\Omega v_t}\right)\right]\exp\left(-\frac{v^2}{2v_t^2}\right)$$

- The kinetic dispersion relation of GDI including finite ion gyro-radius effects is given by:

$$1+\sum_j \chi_j(\omega, k_\perp) = 0 \quad \text{where } j = e, i$$

$$\chi_j(\omega, \vec{k}) = \frac{k_{Dj}^2}{k^2}\left\{1 + \frac{(\omega - \vec{k}\cdot\vec{v}_{nj} - \vec{k}\cdot\vec{v}_{Pj})A_j(\vec{k},\omega) - N_j(\vec{k},\omega)}{1 + i\nu_j A_j(\vec{k},\omega) - i(v_{pj}/v_{tj})R_{xj}(\vec{k},\omega)}\right\}$$

$$\text{where } A_j(\vec{k},\omega) = \frac{\exp(-b_j)}{\sqrt{2}k_\parallel v_{tj}} I_o(b_j) Z(\zeta),$$

$$R_{xj}(\vec{k},\omega) = \frac{ik_y v_{tj}}{\sqrt{2}k_\parallel v_{tj}} \exp(-b_j)[I_o(b_j) - I'_o(b_j)]Z(\zeta),$$

$$R_{yj}(\vec{k},\omega) = -\frac{\Omega_j}{k_y v_{tj}}[1 + \frac{\omega + i\nu_j}{\sqrt{2}k_\parallel v_{tj}} \exp(-b_j) I_o(b_j) Z(\zeta), \ \ and$$

$$N(\vec{k},\omega) = \frac{\omega(v_{nj} + v_{Pj})}{\Omega_j v_{tj}} R_{yj}(\vec{k},\omega) + \frac{\omega \nu_j v_{nj}}{\Omega_j^2 v_{tj}} R_{xj}(\vec{k},\omega)$$

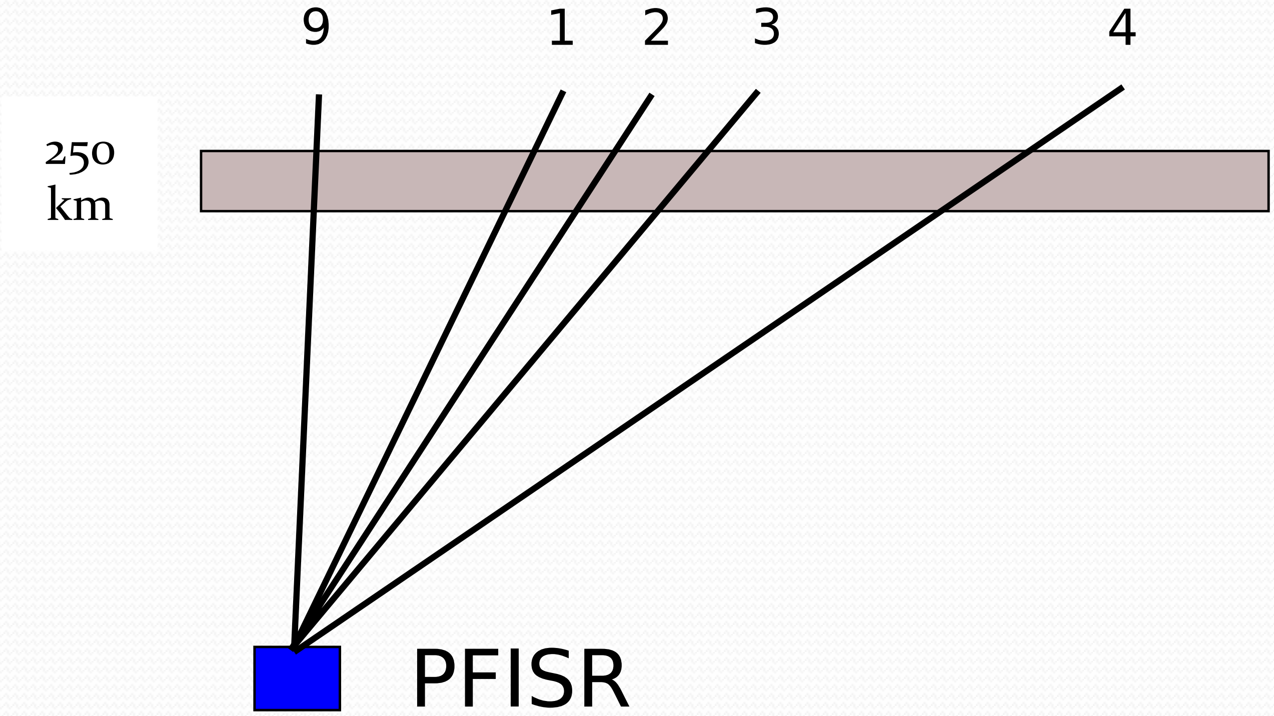
Overview Of the experiment

- Objectives
- Introduction.
- Experiment design and beam pattern.
- Data processing
- Data results.
- Science!
- Conclusions.

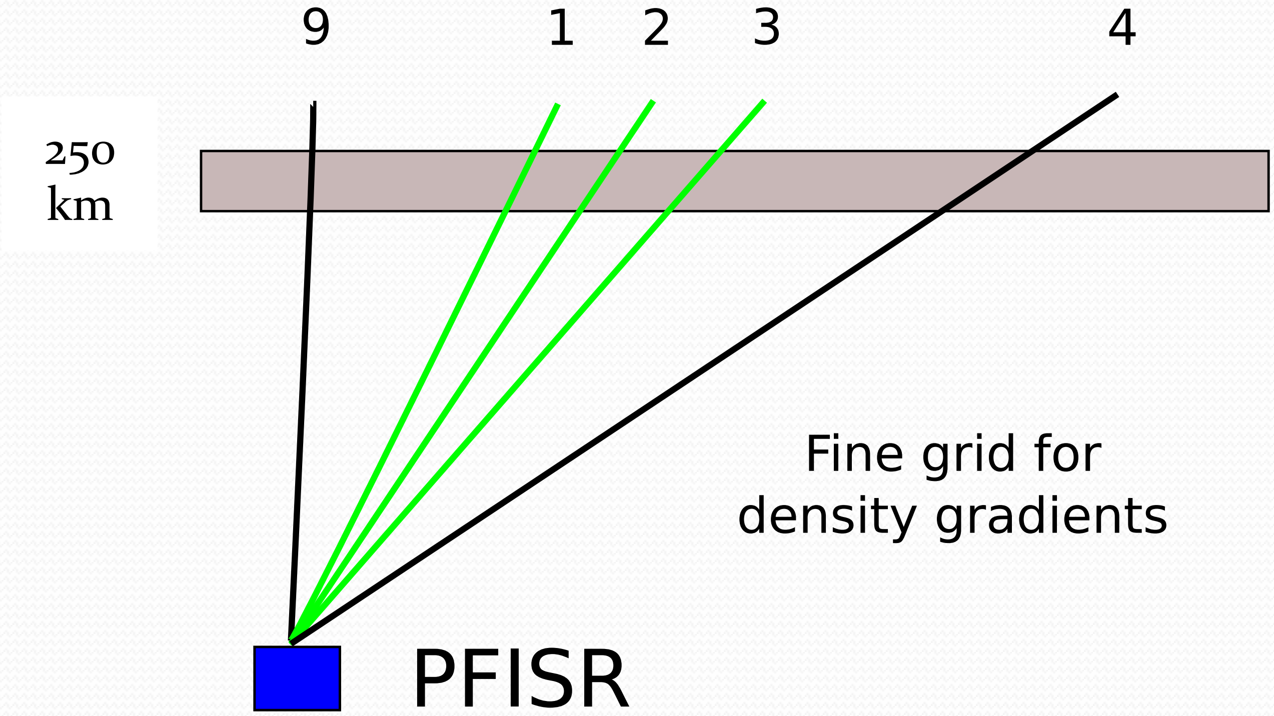
Science Objectives

- Study F-region nighttime high-latitude irregularities at altitude 250 km, using horizontal gradients for both electron temperature and density.
- Correlate incoherent scatter radar data with other measurements, including Fabry-Perot Interferometer and SuperDARN.
- A critical comparison of TGI and GDI will be made the development of the growth rate time series of both TGI and GDI relevant to the ISR observations at altitude of 250 km.

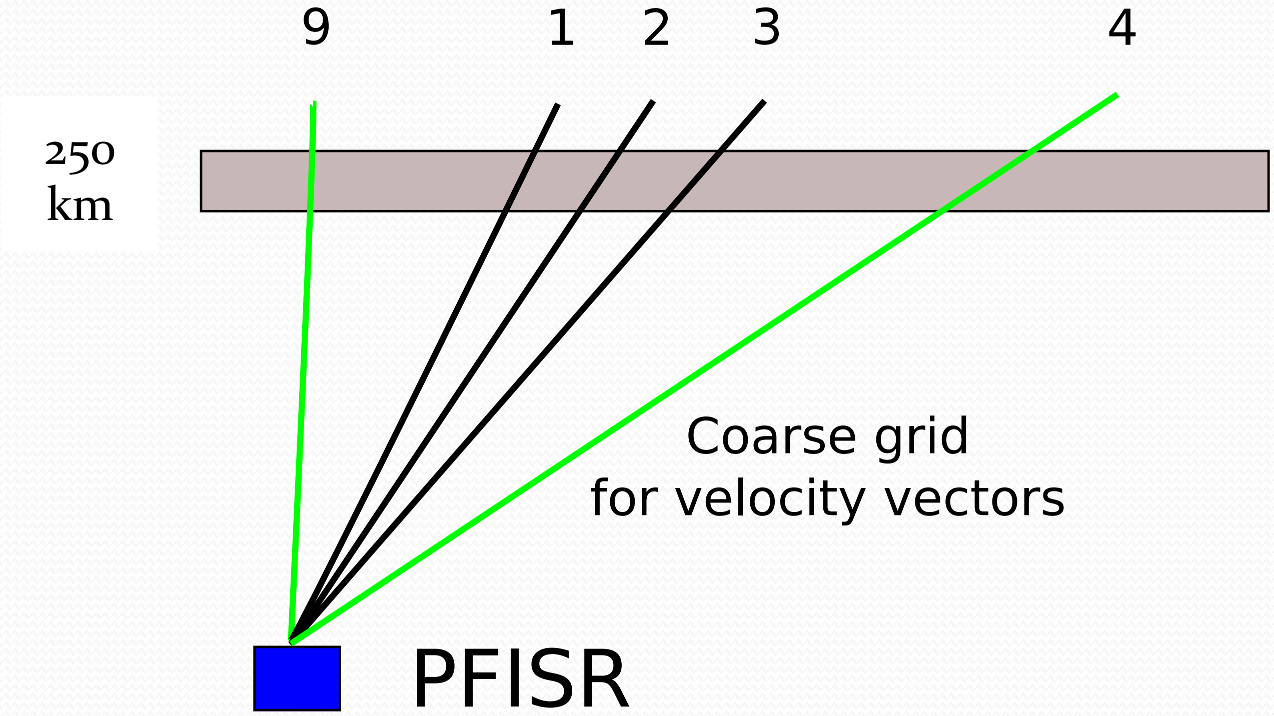
Beam Scheme



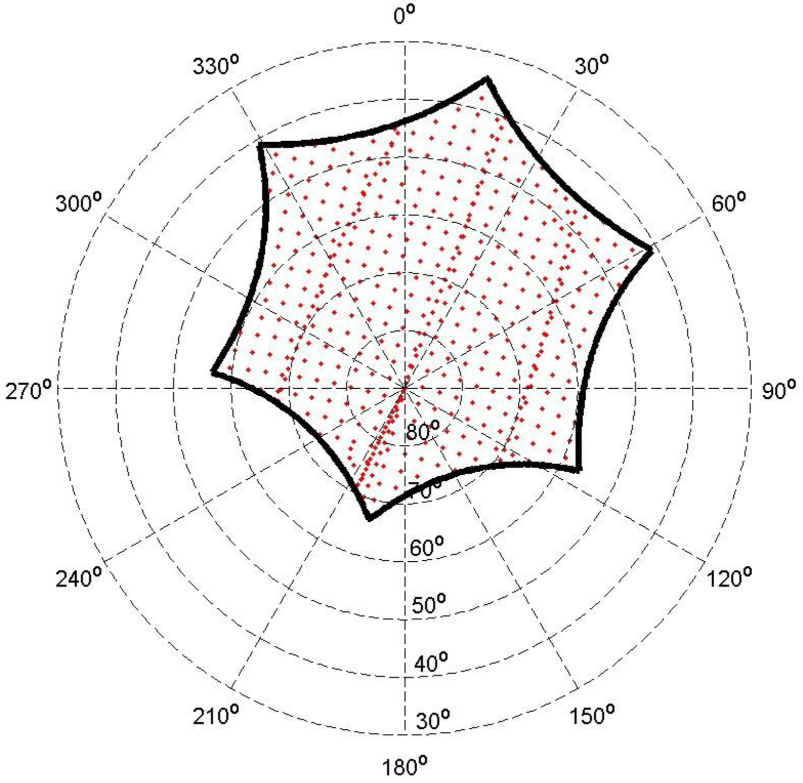
Beam Scheme



Beam Scheme

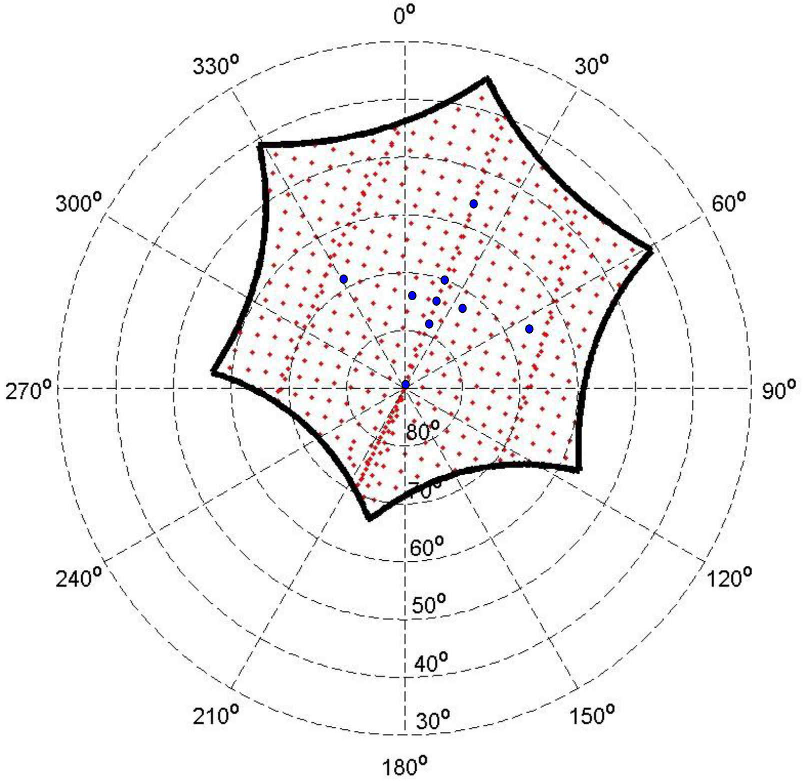


Poker Flat Incoherent Scatter Radar (PFISR)



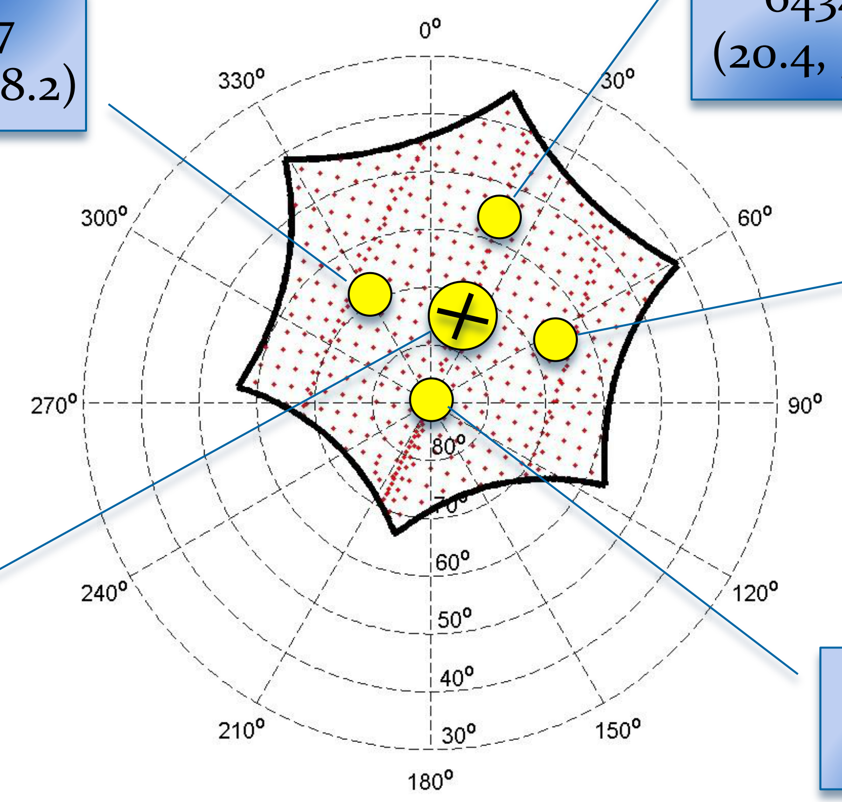
Available PFISR Beams

Poker Flat Incoherent Scatter Radar (PFISR)



Available PFISR Beams

Poker Flat Incoherent Scatter Radar (PFISR)



64967
(-29.2, 68.2)

64349
(20.4, 55.9)

65000
(64.6, 66.0)

64034 (20.5, 78.0)
64040 (20.5, 74.0)
64046 (20.5, 70.0)
64988 (35.9, 72.9)
64979 (4.23, 73.3)

65291
(15.0, 89.0)

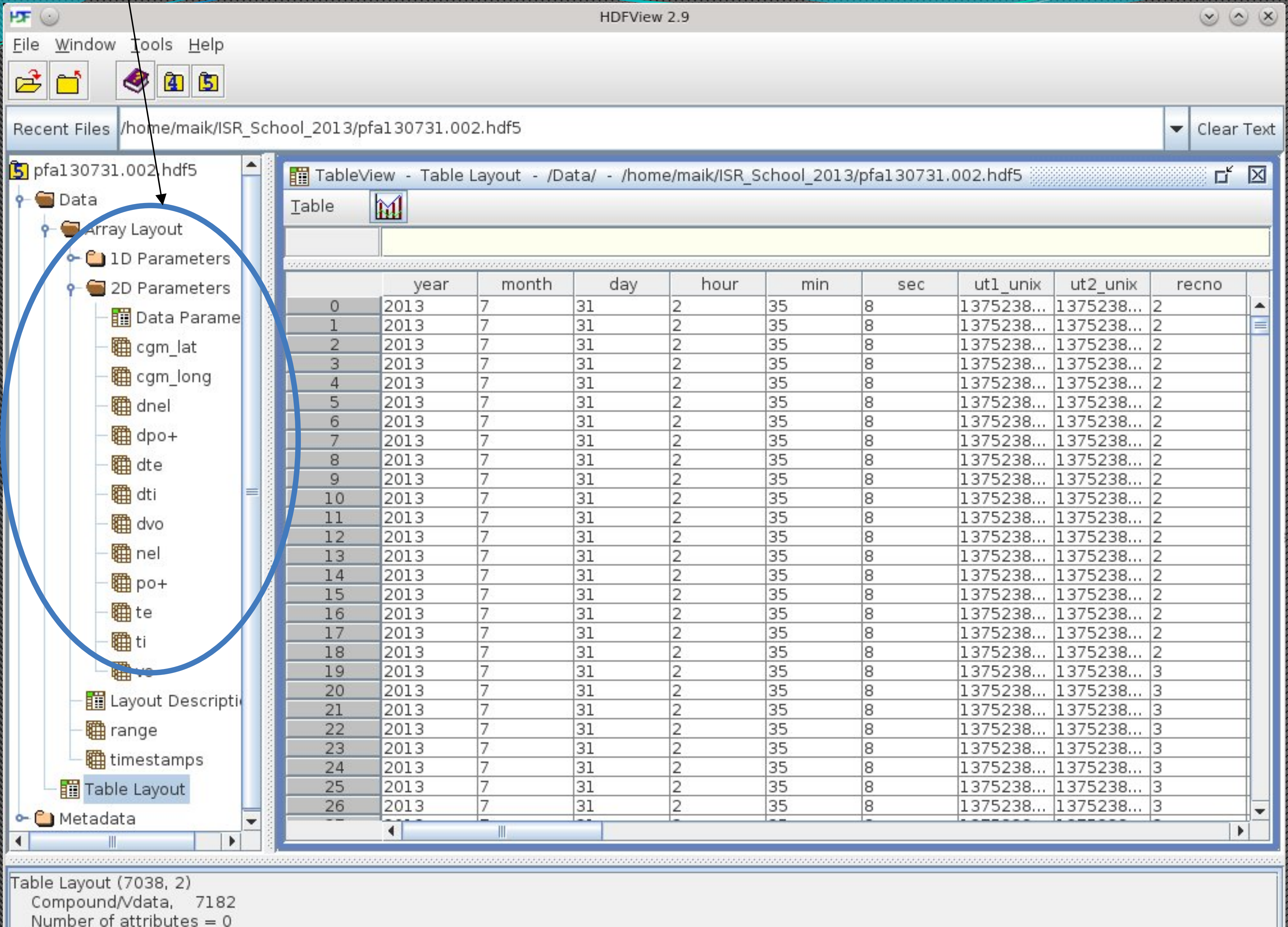
Available PFISR Beams

Data Retrieval

- Two places to download the data from:
  - http://cedar.openmadrigal.org/
  - http://amisr.com/database/
- Why do these two files have different content?
- How are the different beams stored in the data?

only one beam?

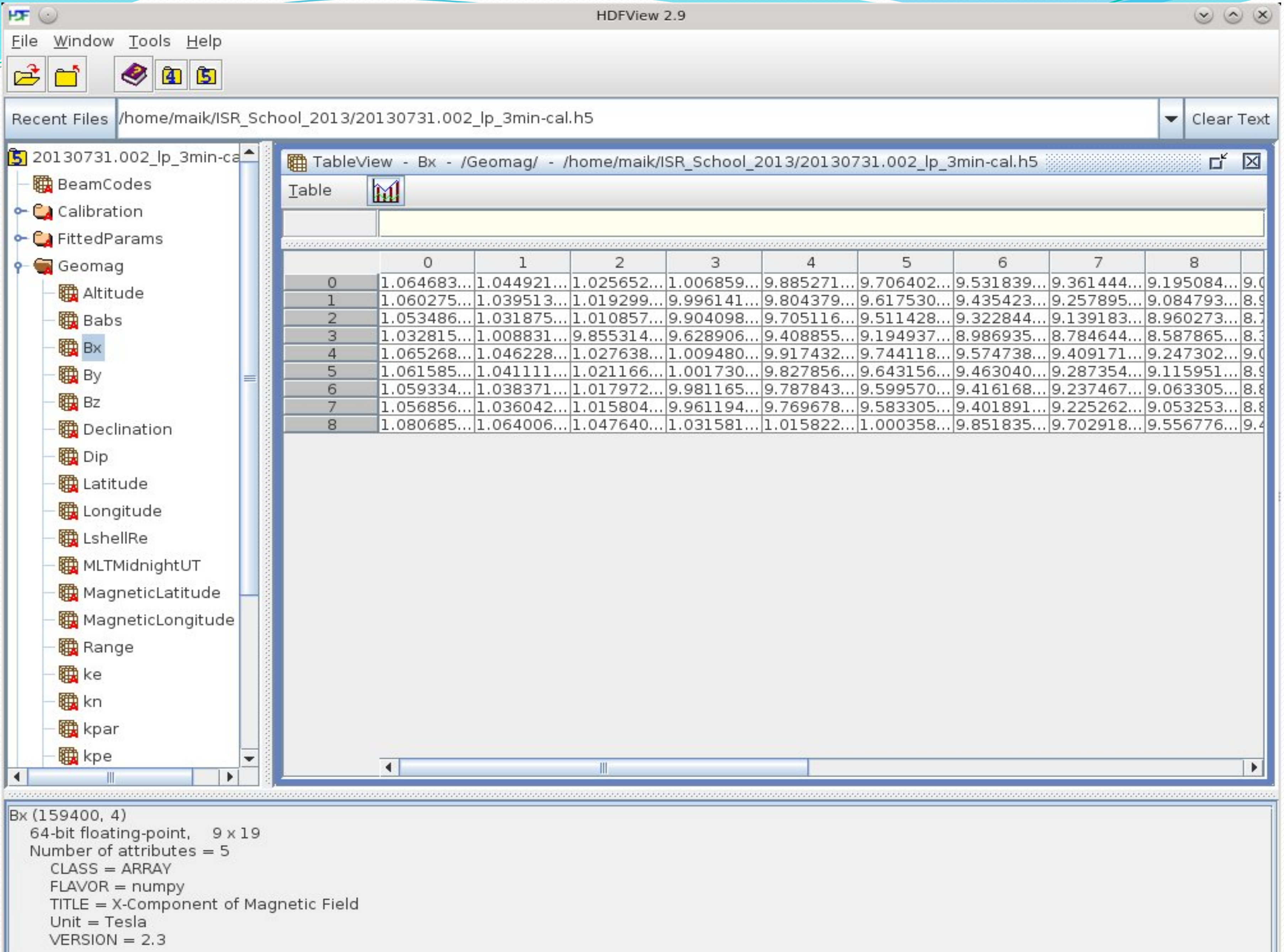
From CEDAR server



	year	month	day	hour	min	sec	ut1_unix	ut2_unix	recno
0	2013	7	31	2	35	8	1375238...	1375238...	2
1	2013	7	31	2	35	8	1375238...	1375238...	2
2	2013	7	31	2	35	8	1375238...	1375238...	2
3	2013	7	31	2	35	8	1375238...	1375238...	2
4	2013	7	31	2	35	8	1375238...	1375238...	2
5	2013	7	31	2	35	8	1375238...	1375238...	2
6	2013	7	31	2	35	8	1375238...	1375238...	2
7	2013	7	31	2	35	8	1375238...	1375238...	2
8	2013	7	31	2	35	8	1375238...	1375238...	2
9	2013	7	31	2	35	8	1375238...	1375238...	2
10	2013	7	31	2	35	8	1375238...	1375238...	2
11	2013	7	31	2	35	8	1375238...	1375238...	2
12	2013	7	31	2	35	8	1375238...	1375238...	2
13	2013	7	31	2	35	8	1375238...	1375238...	2
14	2013	7	31	2	35	8	1375238...	1375238...	2
15	2013	7	31	2	35	8	1375238...	1375238...	2
16	2013	7	31	2	35	8	1375238...	1375238...	2
17	2013	7	31	2	35	8	1375238...	1375238...	2
18	2013	7	31	2	35	8	1375238...	1375238...	2
19	2013	7	31	2	35	8	1375238...	1375238...	3
20	2013	7	31	2	35	8	1375238...	1375238...	3
21	2013	7	31	2	35	8	1375238...	1375238...	3
22	2013	7	31	2	35	8	1375238...	1375238...	3
23	2013	7	31	2	35	8	1375238...	1375238...	3
24	2013	7	31	2	35	8	1375238...	1375238...	3
25	2013	7	31	2	35	8	1375238...	1375238...	3
26	2013	7	31	2	35	8	1375238...	1375238...	3

```
Table Layout (7038, 2)
   Compound/Vdata,    7182
   Number of attributes = 0
```

From AMISR server



	0	1	2	3	4	5	6	7	8	
0	1.064683...	1.044921...	1.025652...	1.006859...	9.885271...	9.706402...	9.531839...	9.361444...	9.195084...	9.0
1	1.060275...	1.039513...	1.019299...	9.996141...	9.804379...	9.617530...	9.435423...	9.257895...	9.084793...	8.9
2	1.053486...	1.031875...	1.010857...	9.904098...	9.705116...	9.511428...	9.322844...	9.139183...	8.960273...	8.7
3	1.032815...	1.008831...	9.855314...	9.628906...	9.408855...	9.194937...	8.986935...	8.784644...	8.587865...	8.3
4	1.065268...	1.046228...	1.027638...	1.009480...	9.917432...	9.744118...	9.574738...	9.409171...	9.247302...	9.0
5	1.061585...	1.041111...	1.021166...	1.001730...	9.827856...	9.643156...	9.463040...	9.287354...	9.115951...	8.9
6	1.059334...	1.038371...	1.017972...	9.981165...	9.787843...	9.599570...	9.416168...	9.237467...	9.063305...	8.8
7	1.056856...	1.036042...	1.015804...	9.961194...	9.769678...	9.583305...	9.401891...	9.225262...	9.053253...	8.8
8	1.080685...	1.064006...	1.047640...	1.031581...	1.015822...	1.000358...	9.851835...	9.702918...	9.556776...	9.4

```
Bx (159400, 4)
    64-bit floating-point,    9 x 19
    Number of attributes = 5
        CLASS = ARRAY
        FLAVOR = numpy
        TITLE = X-Component of Magnetic Field
        Unit = Tesla
        VERSION = 2.3
```

Data Processing

- The two files from the two servers have different content because the CEDAR version is actually derived from the AMISR version. The AMISR version is more complete but the CEDAR version is a standardized version.

- There is a bug in the CEDAR version and the 1D and 2D fields in the CEDAR version should not be used.

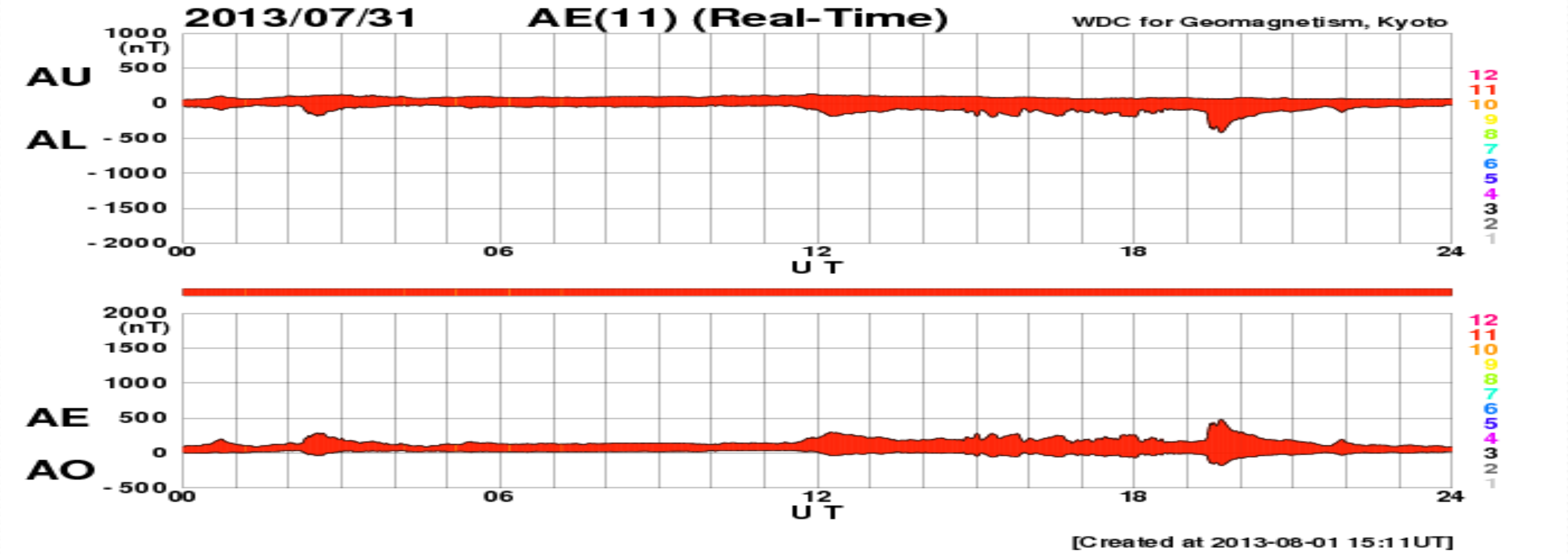
- We used the "Table Layout" field in the "CEDAR" version – apparently that was a good choice

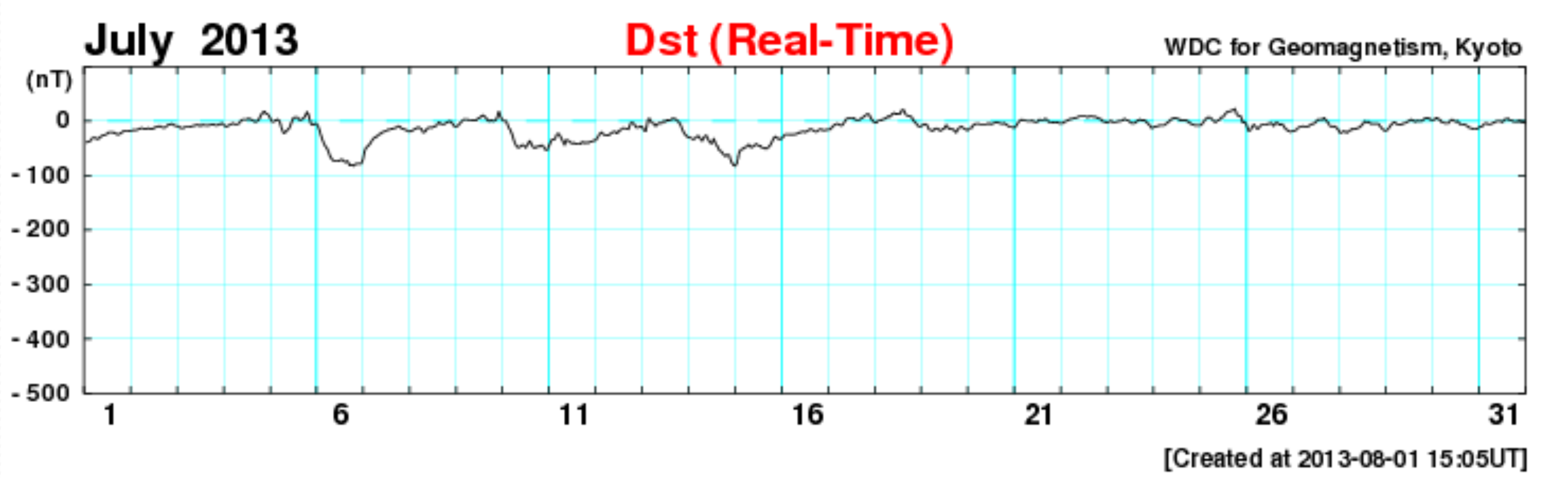
- A simple Python code reads the h5 file, does some sorting, and either produces the necessary plots or puts out text files that we were able to feed easily into Matlab.

Python Code

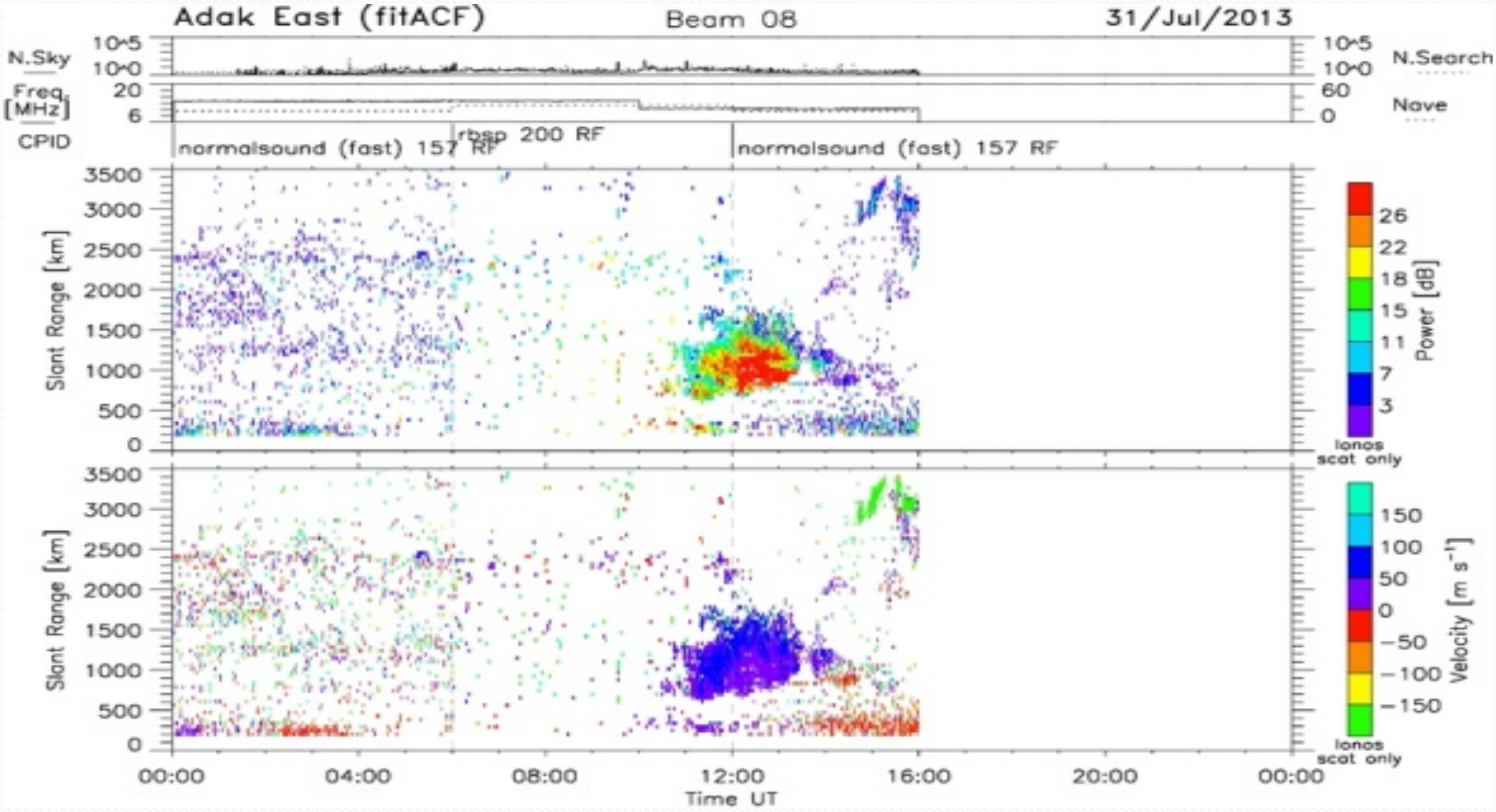
```
import h5py
import numpy as np
import datetime

import matplotlib.pyplot as plt


# This opens the h5 file

f = h5py.File('/home/maik/ISR_School_2013/pfa130731.002.hdf5', 'r', driver='core')


y = []
x = []
for i in range(f['Data/Table Layout'].shape[0]):
  ut1 = datetime.datetime.utcfromtimestamp(f['Data/Table Layout'][i][6])
  range_km = f['Data/Table Layout'][i][11]
  altitude = f['Data/Table Layout'][i][36]
  beamid = f['Data/Table Layout'][i][14]
  nel = f['Data/Table Layout'][i][22]
  te = f['Data/Table Layout'][i][26]
  alt = f['Data/Table Layout'][i][36]
  if beamid==64034 and np.abs(alt)>0 and np.abs(nel)>0 and np.abs(te)>0:
    x.append( alt )
    y.append( te )

    print alt, nel, te


plt.plot(x,y)

plt.show()
```

Geomagnetic Indices

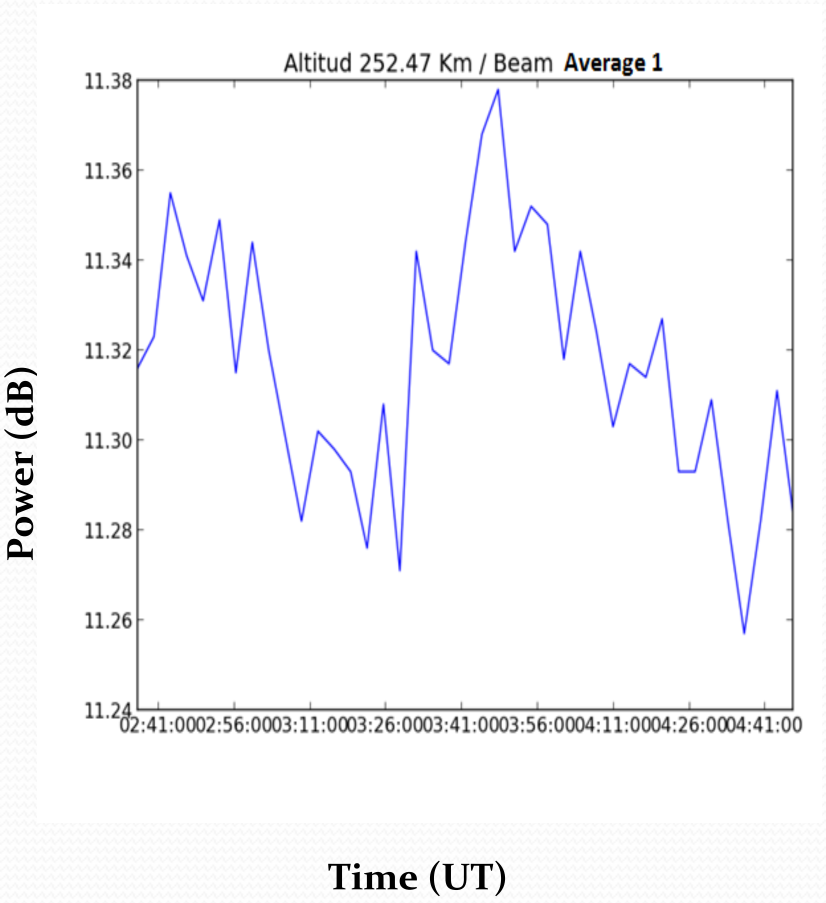


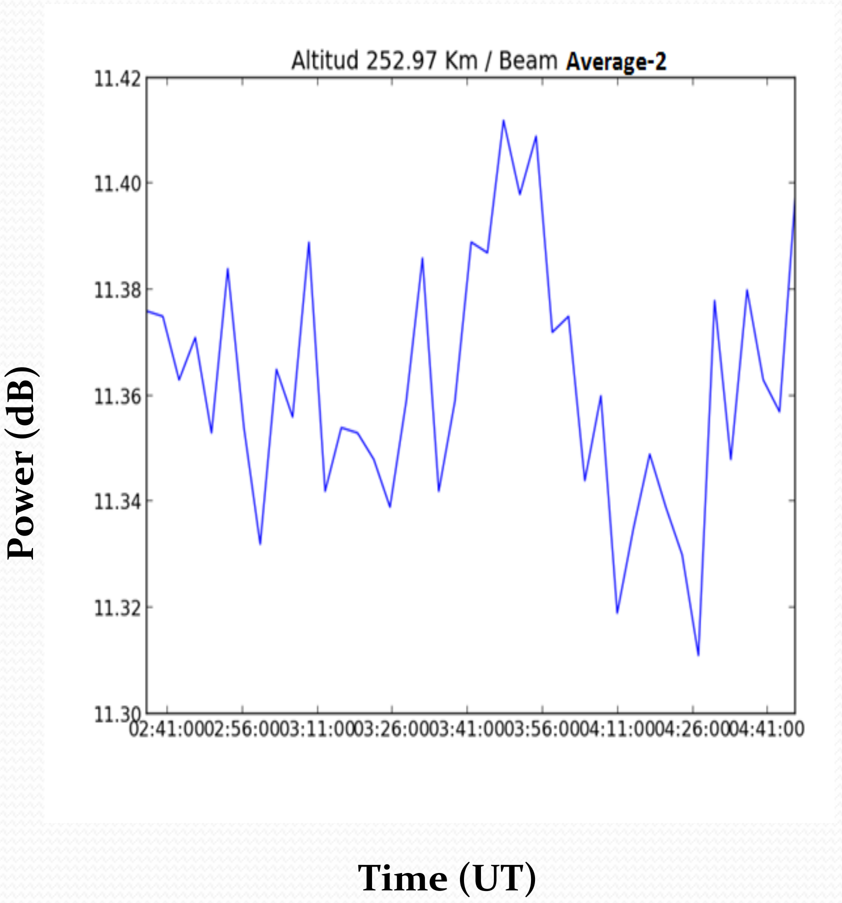


SuperDARN Range-Time Plots

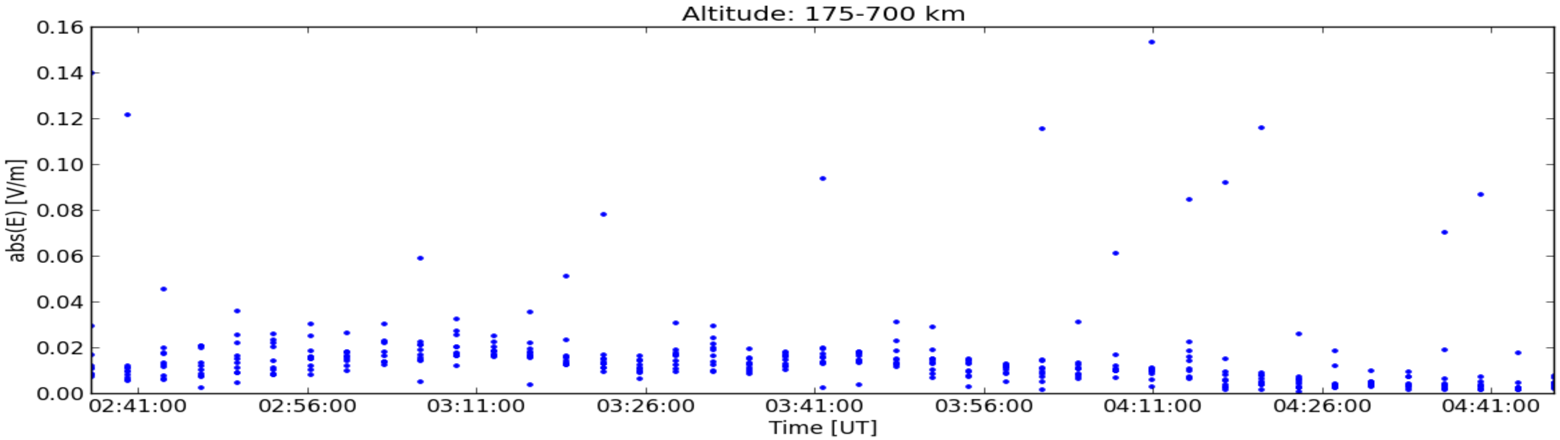


Temporal variation in backscattered Power at 250 km altitude

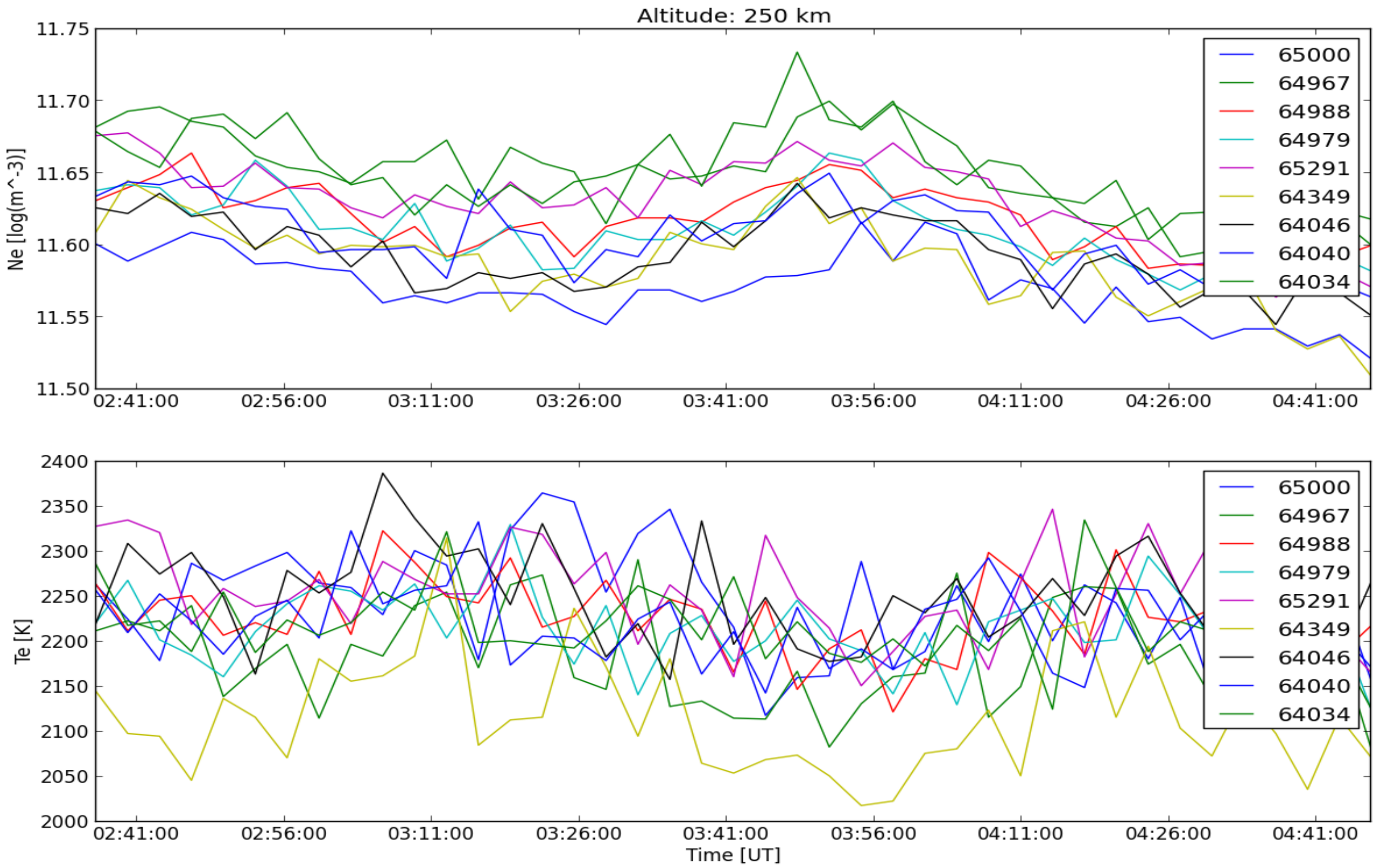




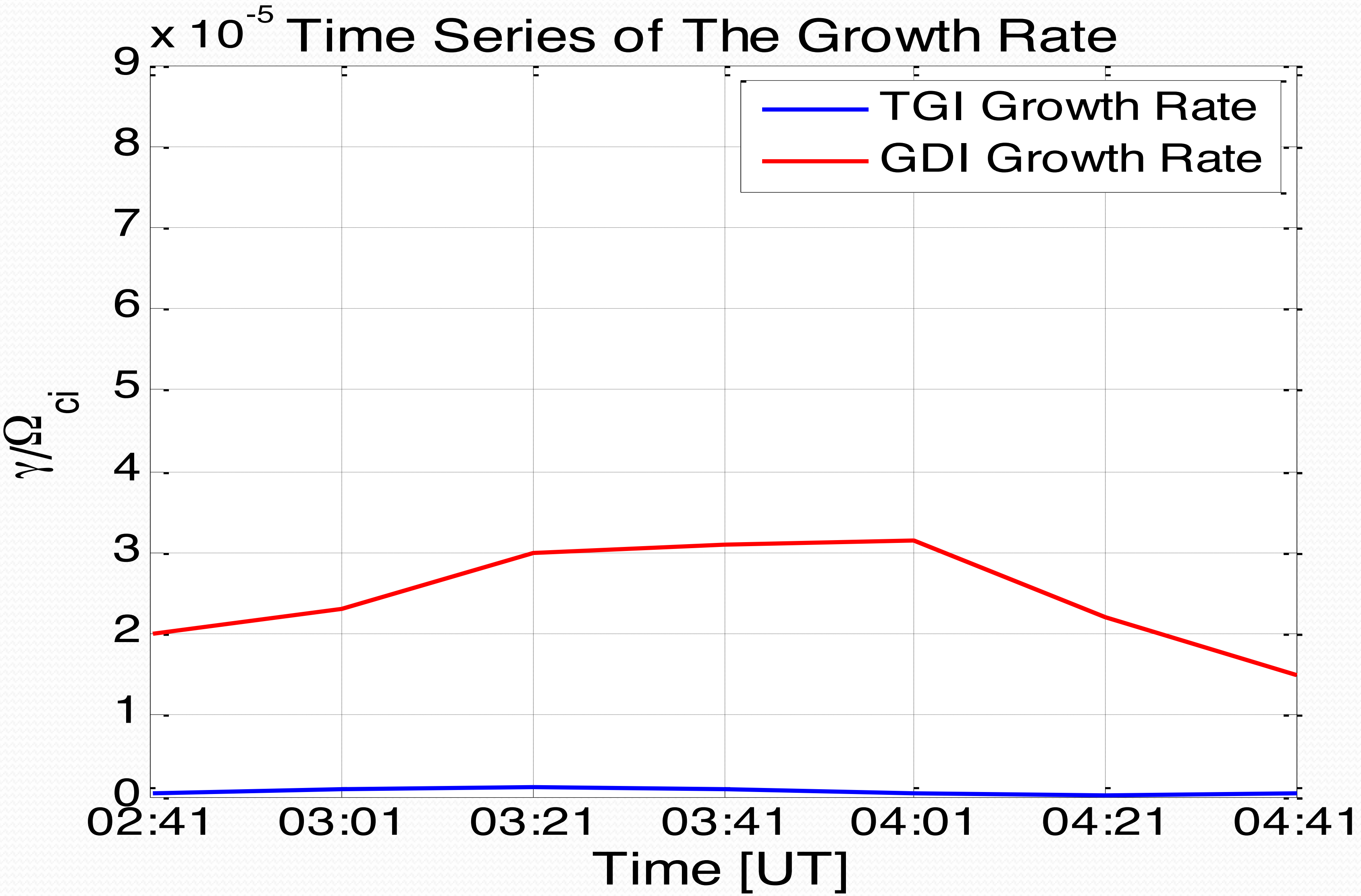
Temporal variations of electric fields at 250 km altitude



Temporal variations of electron density and temperature at 250 km altitude



Growth Rate Time Series



Thank You