Incoherent scatter measurements of F-region temperatures with the Jicamarca radar beam pointing perpendicular to B

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Outline

- **Motivation**
- Experiment Setup and Data
- Forward Model
- Preliminary results

Motivation

- **Objective of this project**:
  - Estimate T_e and T_i of the ionosphere using the ISR technique while pointing the Jicamarca radar beam perpendicular to the Earth’s magnetic field.

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Experiment Setup 1

N-S :"DIFFERENTIAL PHASE"
"ISCOD" = (DGC)
Dr's L.Goncharenko,B.Basu
ANTENNAS"CP=2"
[Nov. 08 - 13, 2004]

Main Antenna Phasing

North Quarter

4/2	4/2	3/5	2/4
4/2	3/5	2/4	2/4
3/5	2/4	5/3	5/3
2/4	2/4	5/3	4/2

East Quarter

5/3	5/3	4/2	3/5
5/3	4/2	3/5	3/5
4/2	3/5	2/4	2/4
3/5	3/5	2/4	5/3

West Quarter

2/4	2/4	5/3	4/2
2/4	5/3	4/2	4/2
5/3	4/2	3/5	3/5
4/2	4/2	3/5	2/4

South Quarter

3/5	3/5	2/4	5/3
3/5	2/4	5/3	5/3
2/4	5/3	4/2	4/2
5/3	5/3	4/2	3/5

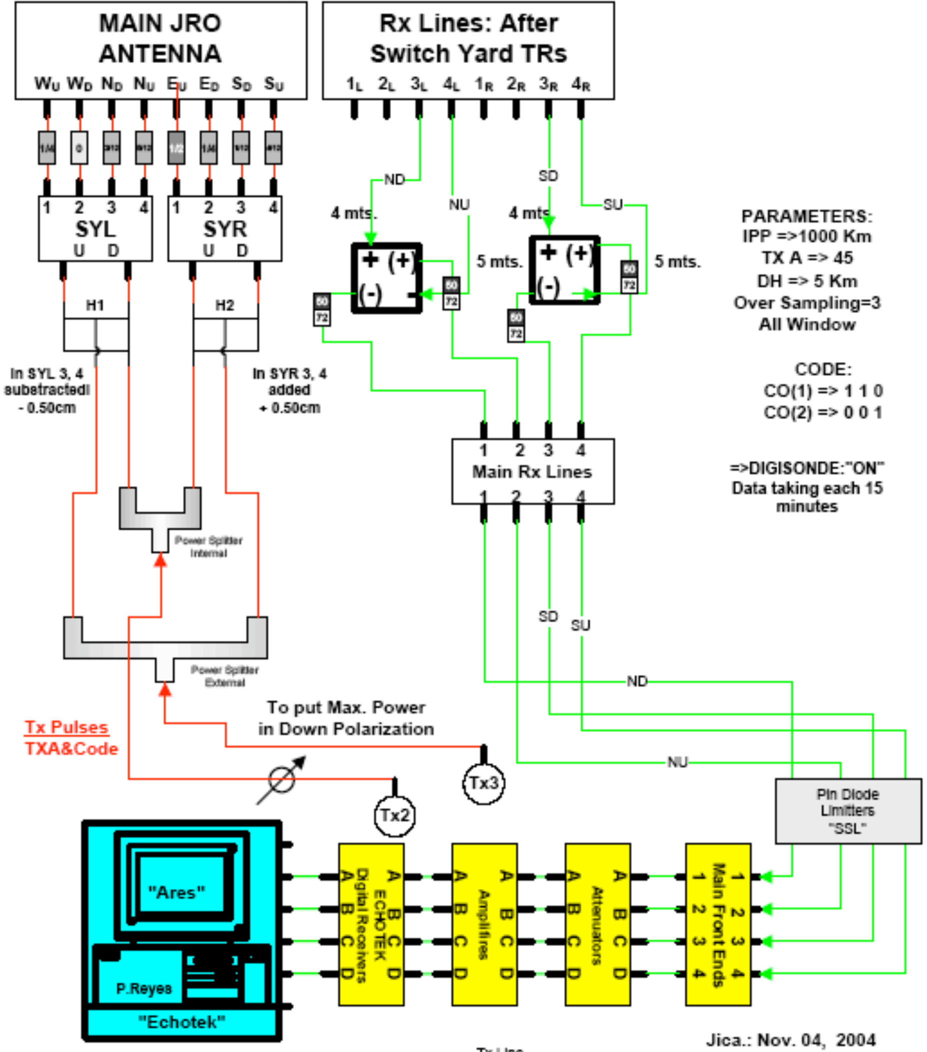
<u>Reference to Ochs Original Manual</u>
This configuration is relative new, first used by Dr. R. Woodman, 10/06/1996
Know by Jicamarca staff as "CP=2"
Perpendicualr to "B"

Jica./04/11/2004
J.G.Vera Azpilcueta

"DIFFERENTIAL PHASE":
"ISCOD" = (DGC)
Nov. 08 - 13, 2004
Dr's: L.Goncharenko,B.Basu

ANTENNA: CP = 2
Differential Phase
Modif.in U's N-S:Up&Dn
(Tipo: E. Kudeki)

Tx / Rx Configuration



In SYL 3, 4 subetractedl - 0.50cm

In SYR 3, 4 added + 0.50cm

To put Max. Power in Down Polarization

<u>Tx Pulses</u>
TXA&Code

PARAMETERS:
IPP =>1000 Km
TX A => 45
DH => 5 Km
Over Sampling=3
All Window

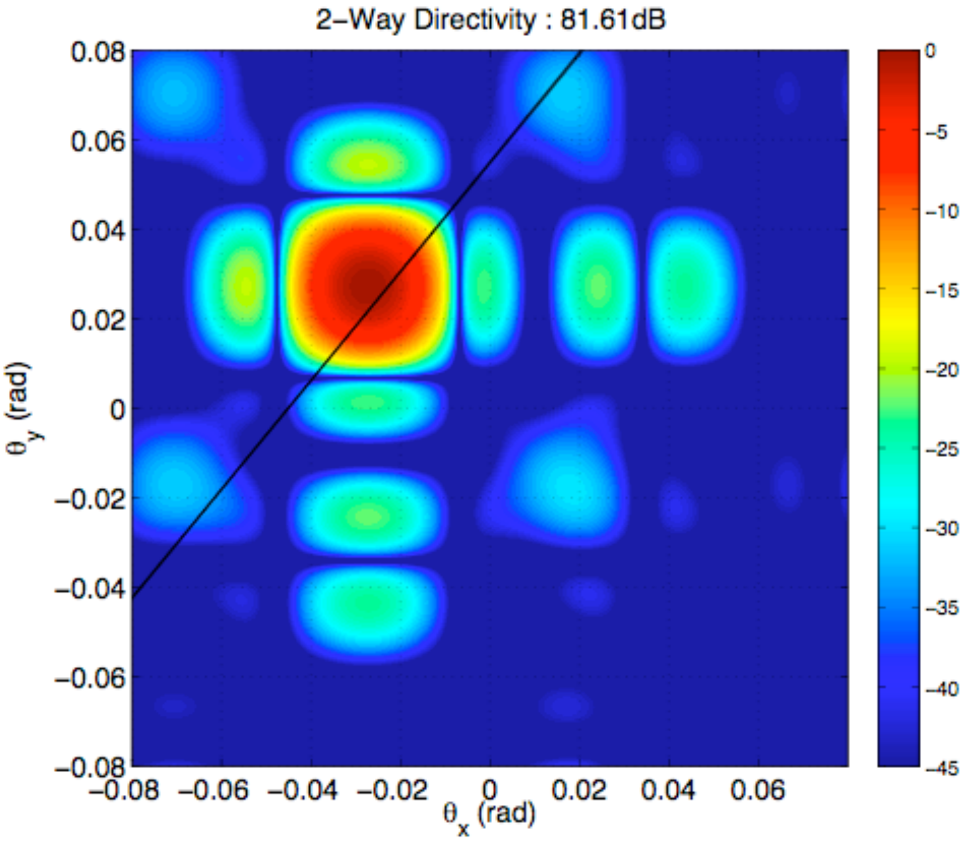
CODE:
CO(1) => 1 1 0
CO(2) => 0 0 1

=>DIGISONDE:"ON"
Data taking each 15 minutes

Jica.: Nov. 04, 2004
"ISCOD" /Differential Phase
Dr.s :J.L.Ch/D.S/ P.R/jgva

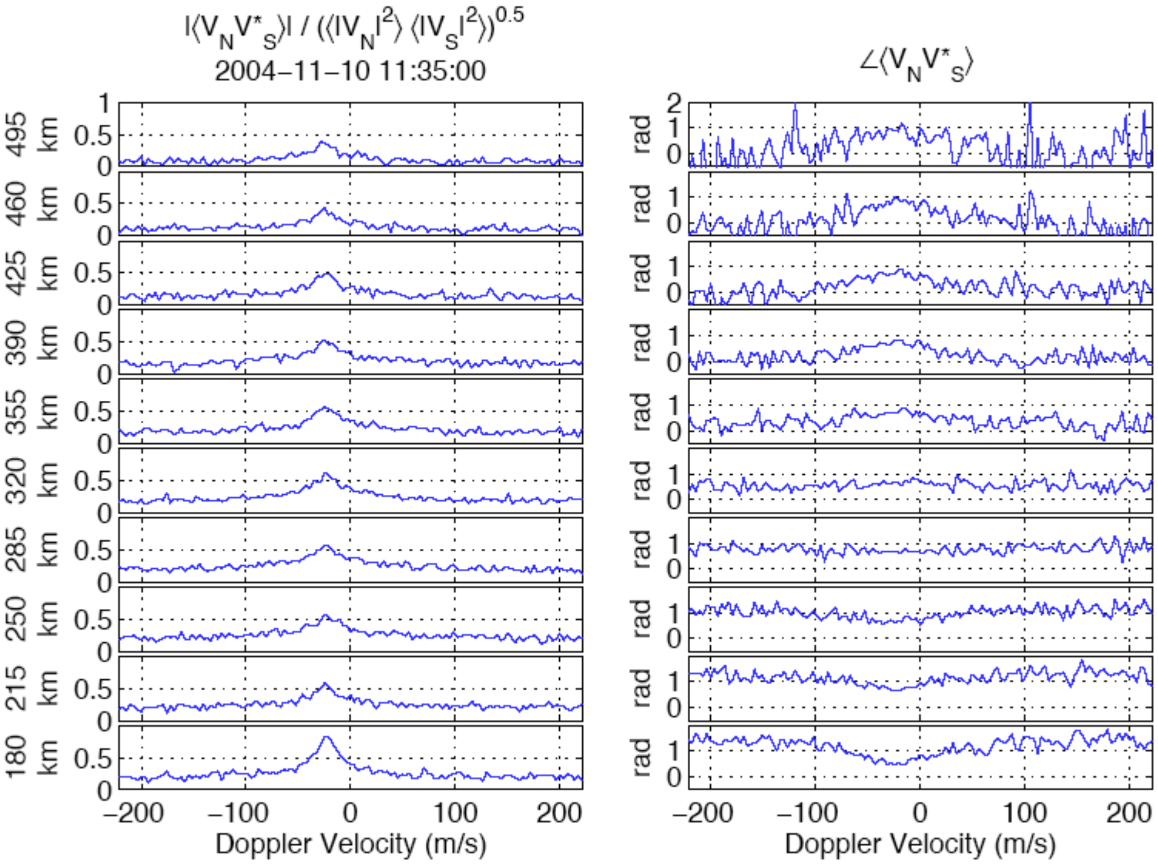
Experimental Setup 2

- Transmit linear pol.
- Receive using 2 quarters N - S, and both pol.
- Meridional and zonal components are synthesized.
- Coherently detected data is acquired in a pulse to pulse basis using matched filter receivers.
- IPP=6.666ms(1000km)
- Tx=15km
- Oversampling =5km
- Range 0-1000km



Sample of coherence Data

- We calculate self spectra and cross spectra.
- 5 min averaged data.



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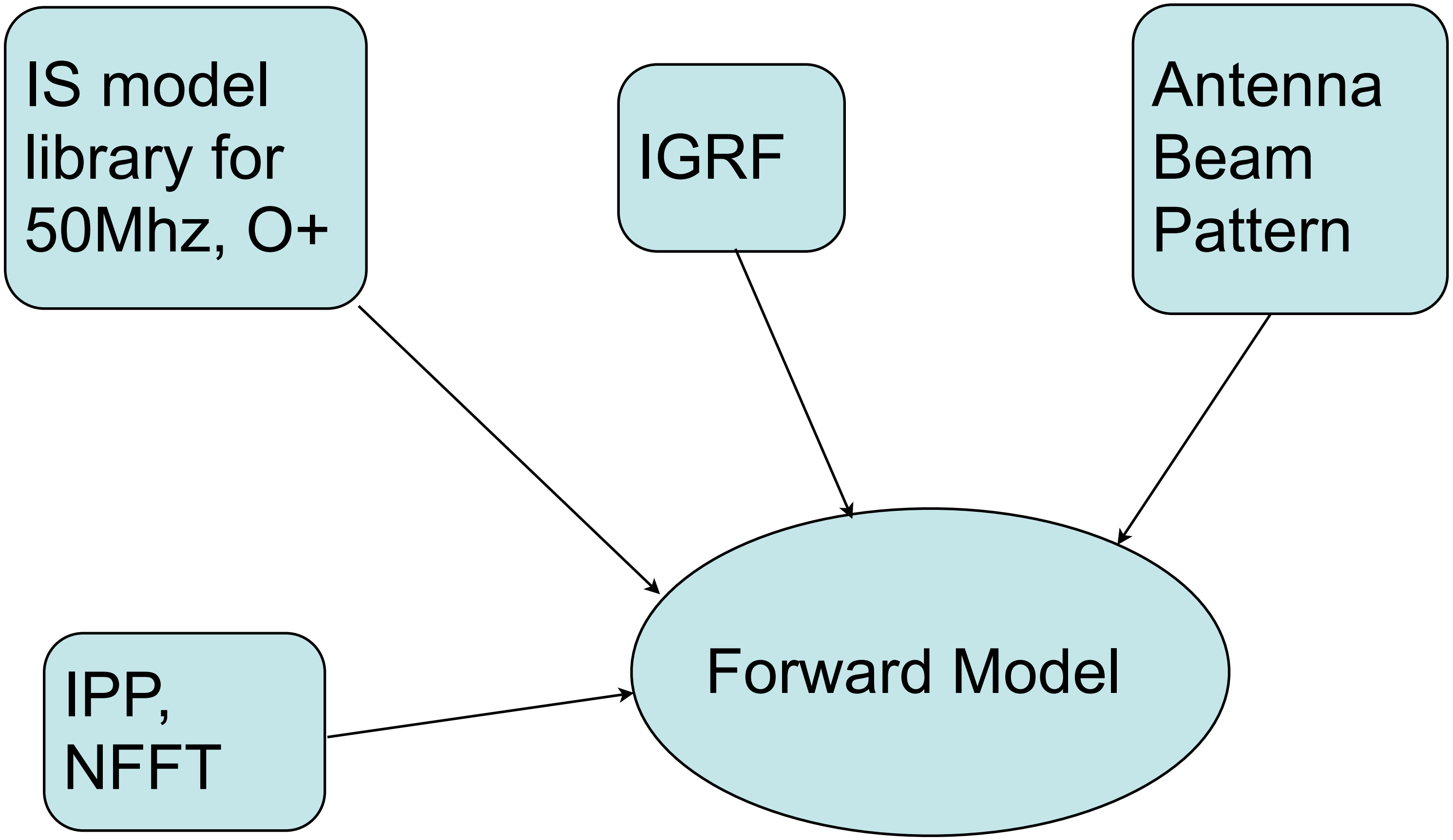
Forward Model 1

- To built the Forward model for the self- and cross-spectra we use:
  - Theoretical ISR Library $\Phi(\alpha,\omega,N_e,T_e,T_i,B_m,O^+)$.
  - Beam pattern of the antenna $G(\theta_x,\theta_y)$
  - IGRF model to get “ α “ in each direction (θ_x,θ_y) within the beam pattern.
  - Geometry of the Interferometer (N-S Antennas baseline = 34.65 λ)
  - Experiment parameters (IPP=1000km = 6.666ms, NFFT=128)

Forward Model 2



IS model library for 50Mhz, O+

IGRF

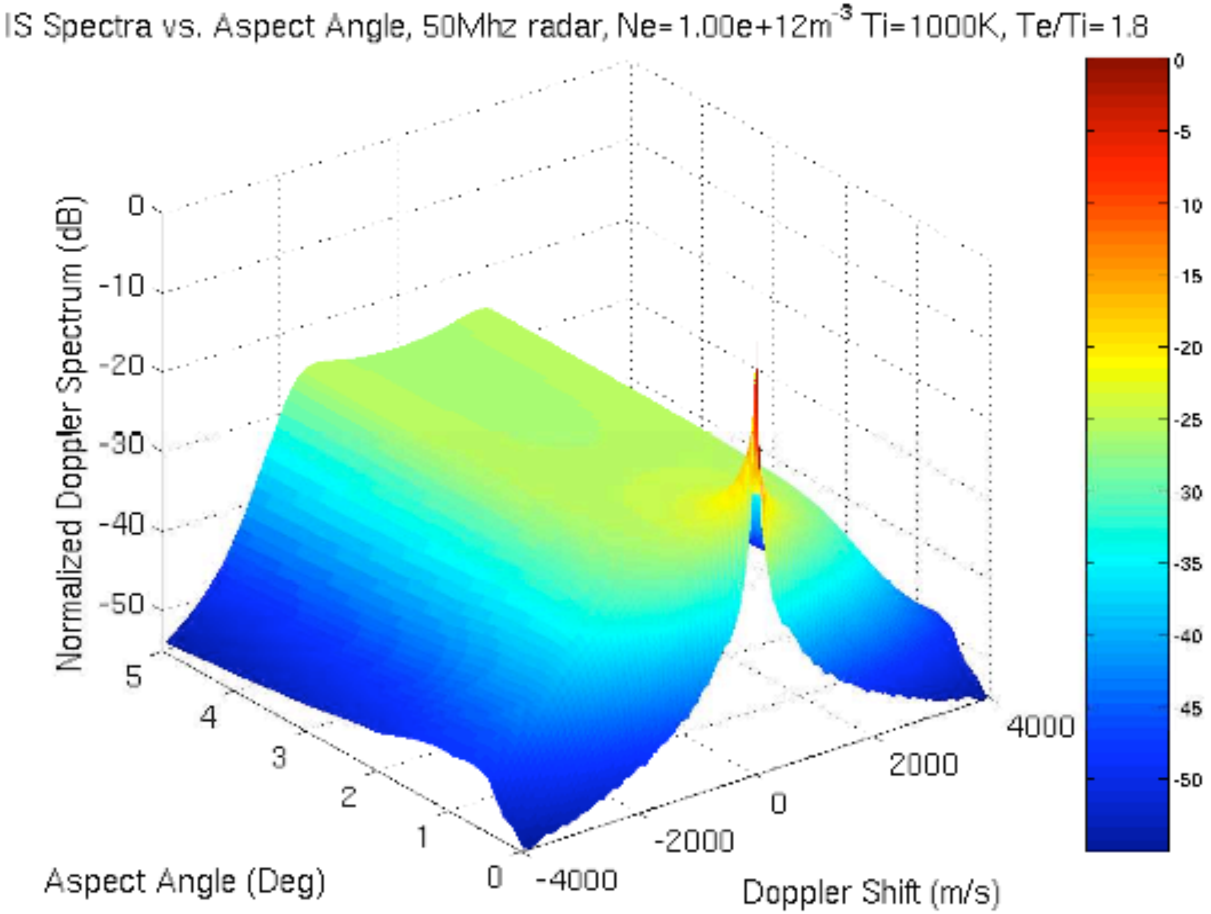
Antenna Beam Pattern

IPP, NFFT

Forward Model

Forward Model 3: IS Spectral Library

- Milla and Kudeki [2008] extended the previous work to all α, building a library based on 3-D random walk Monte Carlo simulations for specific α,B, N_e, T_e and T_i, f_0 (50MHz), ion composition (O^+)



Forward Model 4: Modeling Self-Spectra

Beam-weighted IS spectra received by each antenna:

$$S(\omega) = \iint d\Omega \Phi(\alpha, \omega) G(\theta_x, \theta_y)$$

After discretizing the beam we obtain :

$$S(\omega) = \sum_x \sum_y \frac{\Delta x \Delta y}{\sqrt{1 - x^2 - y^2}} G(x, y) \Phi(A(x, y), \omega)$$

Where A(x,y) is the distribution of α for every direction inside the beam. The IGRF model was used to obtain B:

$$\Lambda(\hat{\alpha}) = \sum_{x_n} \sum_{y_n} \frac{\Delta x \Delta y}{\sqrt{1 - x_n^2 - y_n^2}} G(x_n, y_n) \cdot \delta_{\hat{\alpha}, A(x_n, y_n)}$$

Using this “weighting-function” we compute the self-spectra with:

$$S(\omega) = \sum_{\hat{\alpha}} \Lambda(\hat{\alpha}) \Phi(\hat{\alpha}, \omega)$$

Forward Model 5: Modeling Cross-Spectra

Normalized Beam-weighted IS cross-spectra from N and S antennas:

$$C_{NS}(\omega) = \frac{1}{S(\omega)} \iint d\Omega \Phi(\alpha, \omega) e^{j\vec{D}\cdot\vec{k}} G(\theta_x, \theta_y)$$

where, $\vec{D} = |\vec{D}| \cdot \frac{1}{\sqrt{2}}(-\hat{x} + \hat{y})$,and the wave vector $\vec{k} = \frac{2\pi}{\lambda}\hat{k}$

After discretizing the beam we obtain :

$$C_{NS}(\omega) = \frac{1}{S(\omega)} \sum_{x_n} \sum_{y_n} \frac{\Delta x \Delta y}{\sqrt{1 - x_n^2 - y_n^2}} G(x_n, y_n) e^{j\vec{D}\cdot\vec{k}} \cdot \Phi(A(x, y), \omega)$$

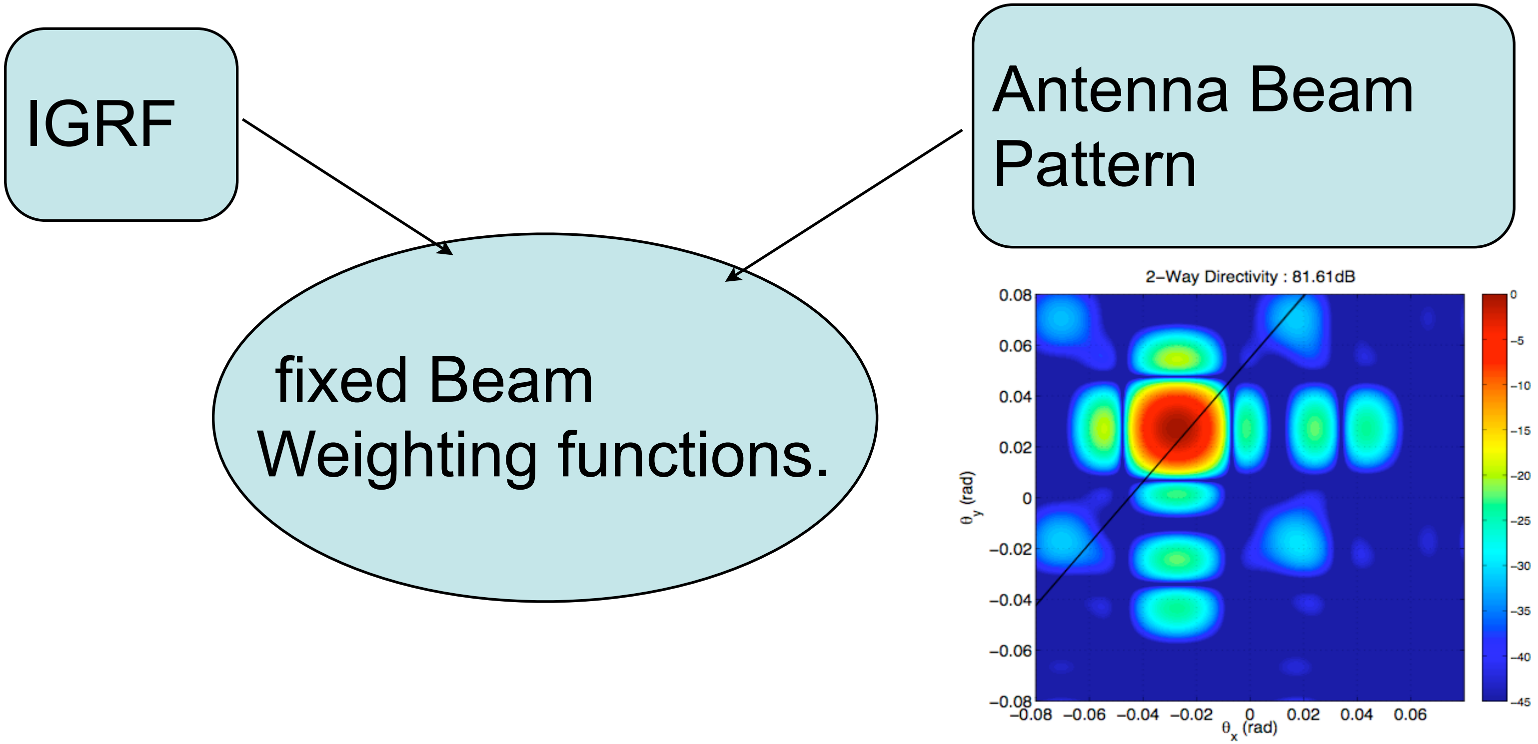
Now we will have a complex weighting-function:

$$\Lambda_{NS}(\hat{\alpha}) = \sum_{x_n} \sum_{y_n} \frac{\Delta x \Delta y}{\sqrt{1 - x_n^2 - y_n^2}} G(x_n, y_n) \delta_{(\hat{\alpha} - A(x_n, y_n)} e^{j\vec{D}\cdot\vec{k}}$$

Final our model for computing coherence:

$$C_{NS}(\omega) = \frac{1}{S(\omega)} \sum_{\hat{\alpha}} \Lambda_{NS}(\hat{\alpha}) \Phi(\hat{\alpha}, \omega)$$

Forward Model 6: Beam Weighting Functions



IGRF

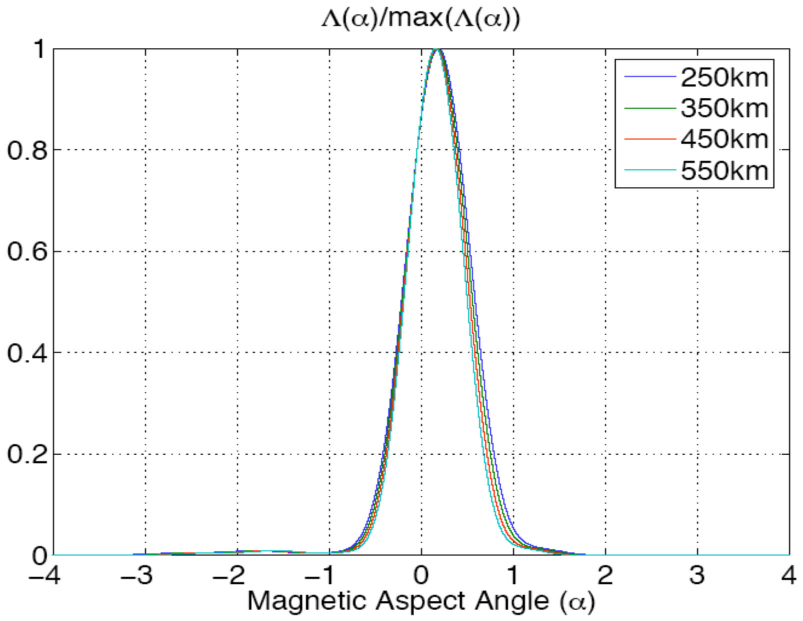
Antenna Beam Pattern

fixed Beam Weighting functions.

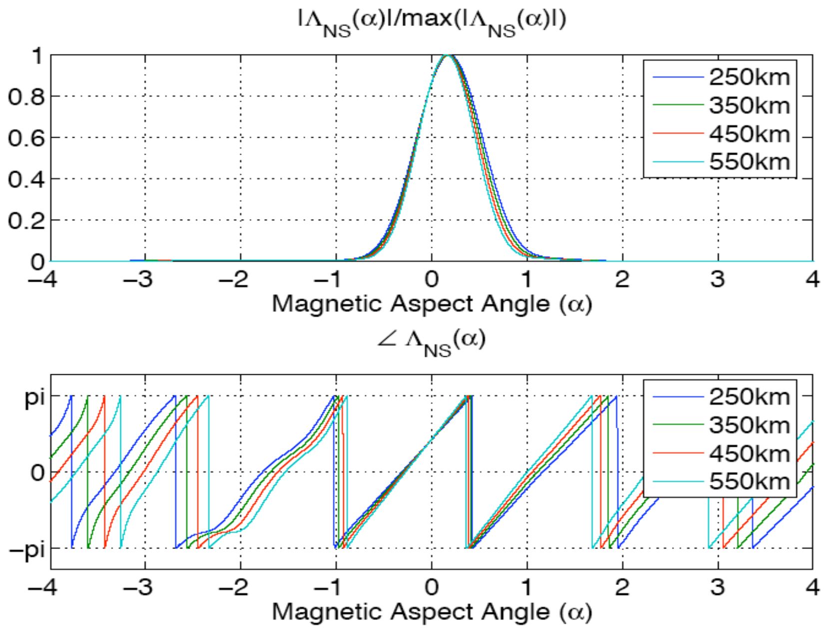
Collapsing the beam pattern in one dimension, so that we have a one dimensional weighting function as a function of aspect angle.

Forward Model 5: Modeling Spectra

Beam weighting function for computing self-spectrum:



Beam weighting function for computing cross-spectrum:



The Next step is:

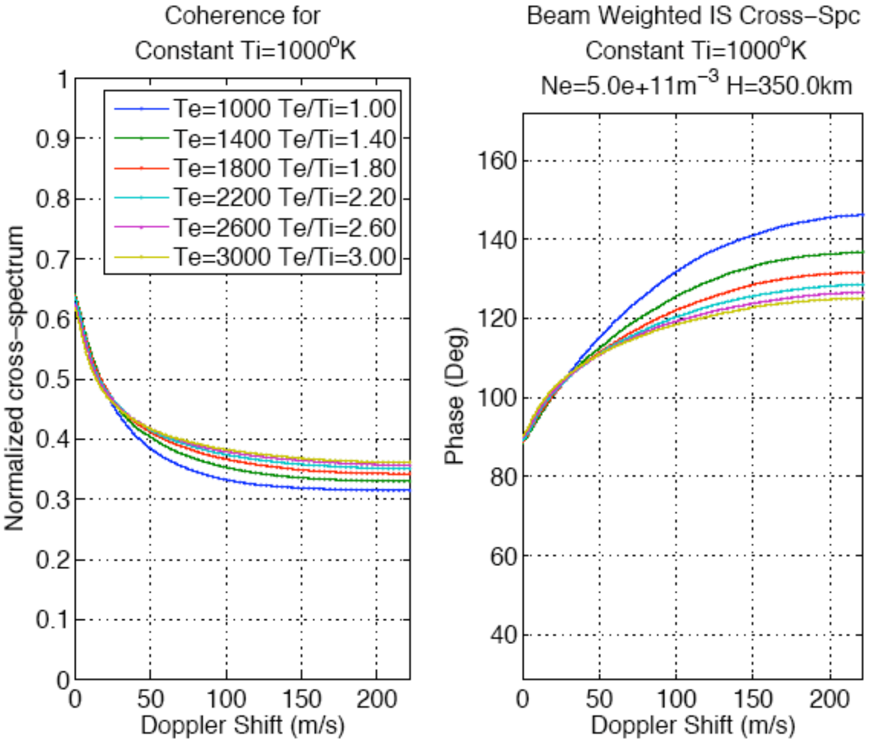
- Make the weighting of the IS for a certain ionosphere with the $\Lambda(\alpha)$ and $\Lambda_{NS}(\alpha)$
- Consider the effect of sampling (IPP=1000km)
- Consider the effect of windowing (NFFT=128)

And we obtain …

Forward Model 6: Some Examples

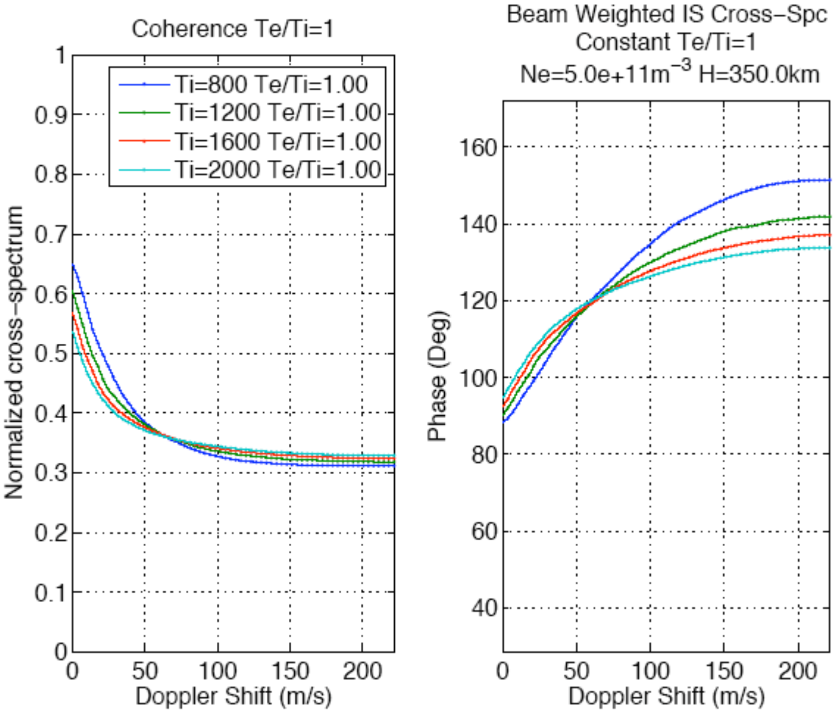
Coherence Spectrum for Jicamarca on November 10,2004

Ti=1000 K



Coherence Spectrum for Jicamarca on November 10,2004,

Constant Te/Ti



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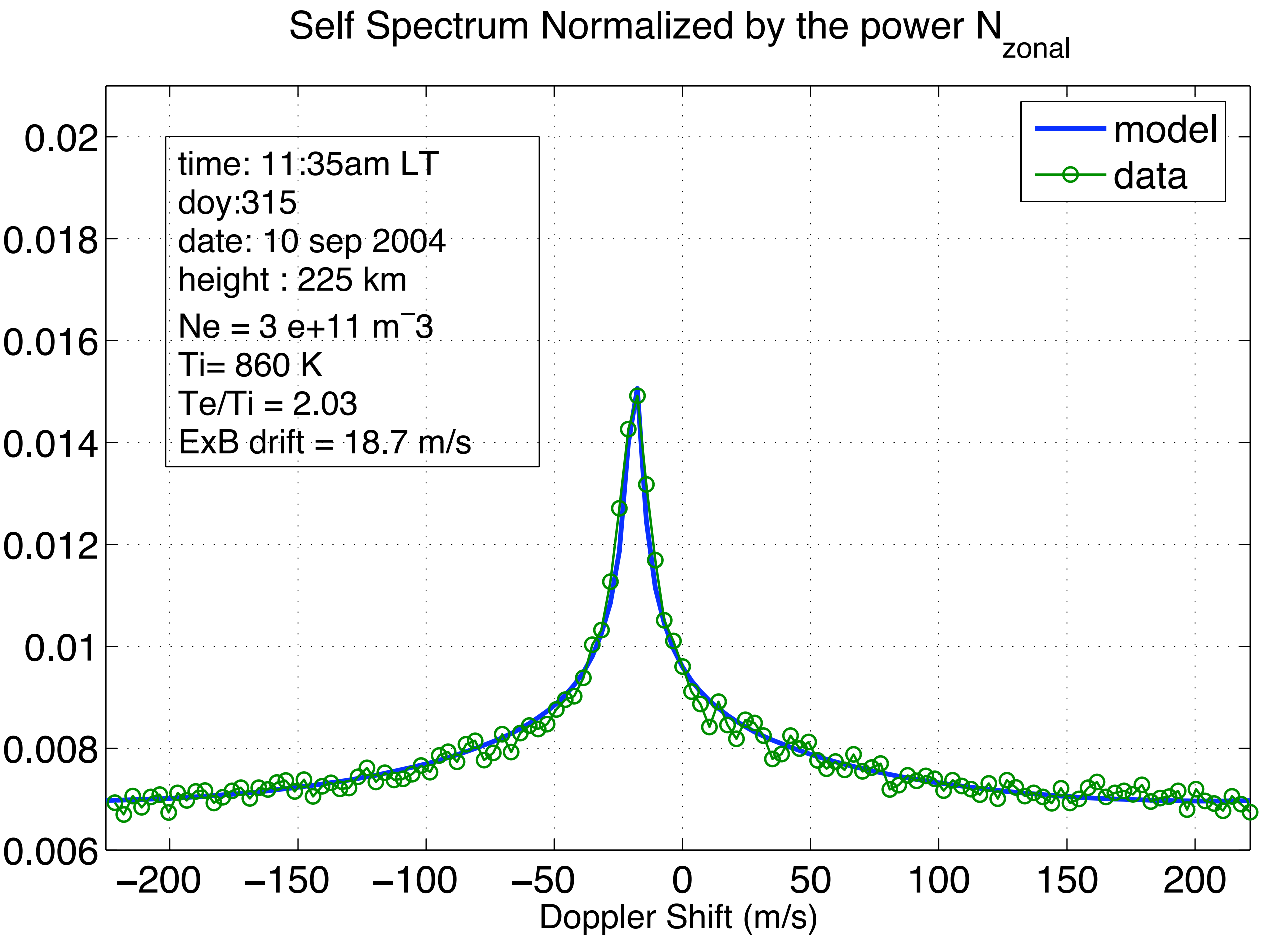
- **Preliminary results**

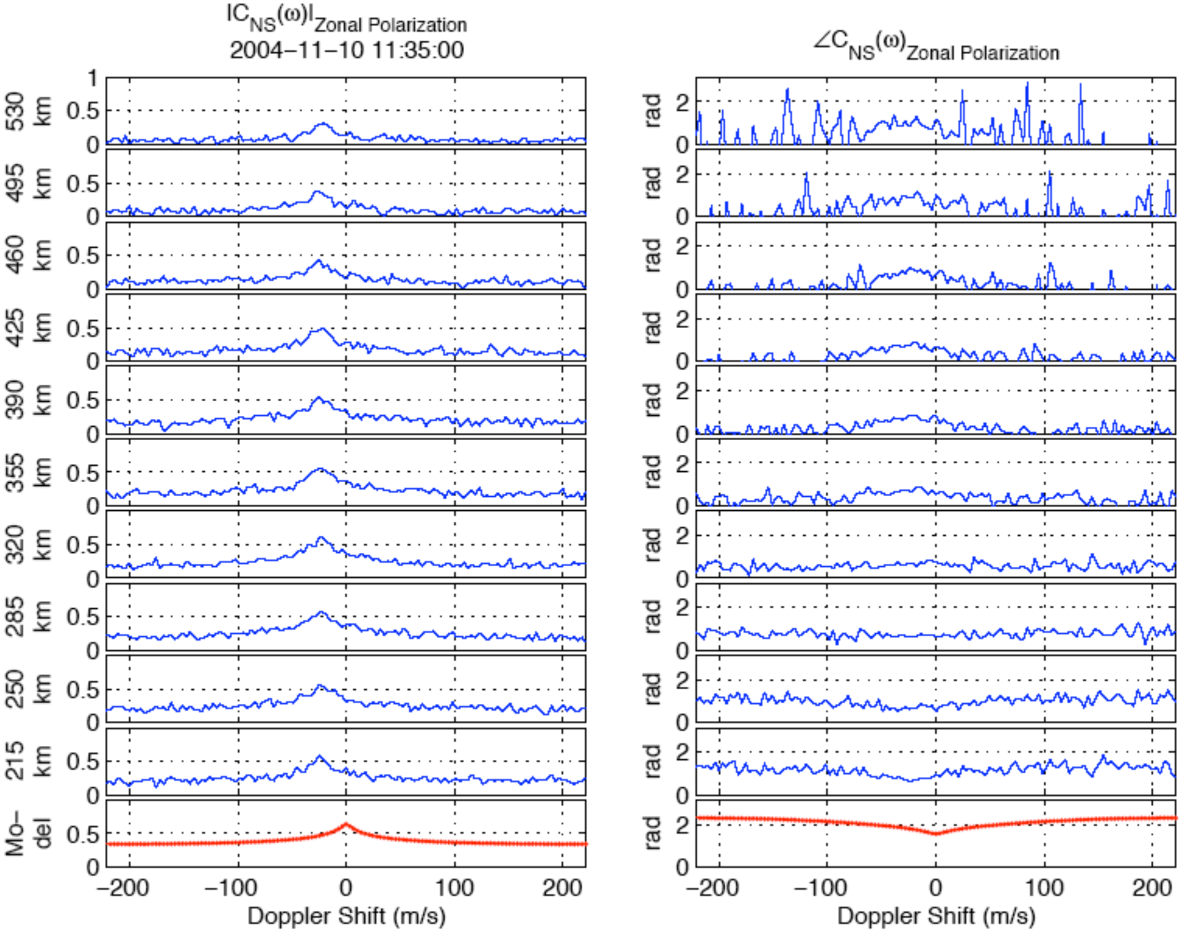
Comparisons between the Data and Model

- Good agreement with the data.
- Temperatures are comparable with IRI model.
- Starting at 225km we don't get contamination of the coherent echoes from 150km

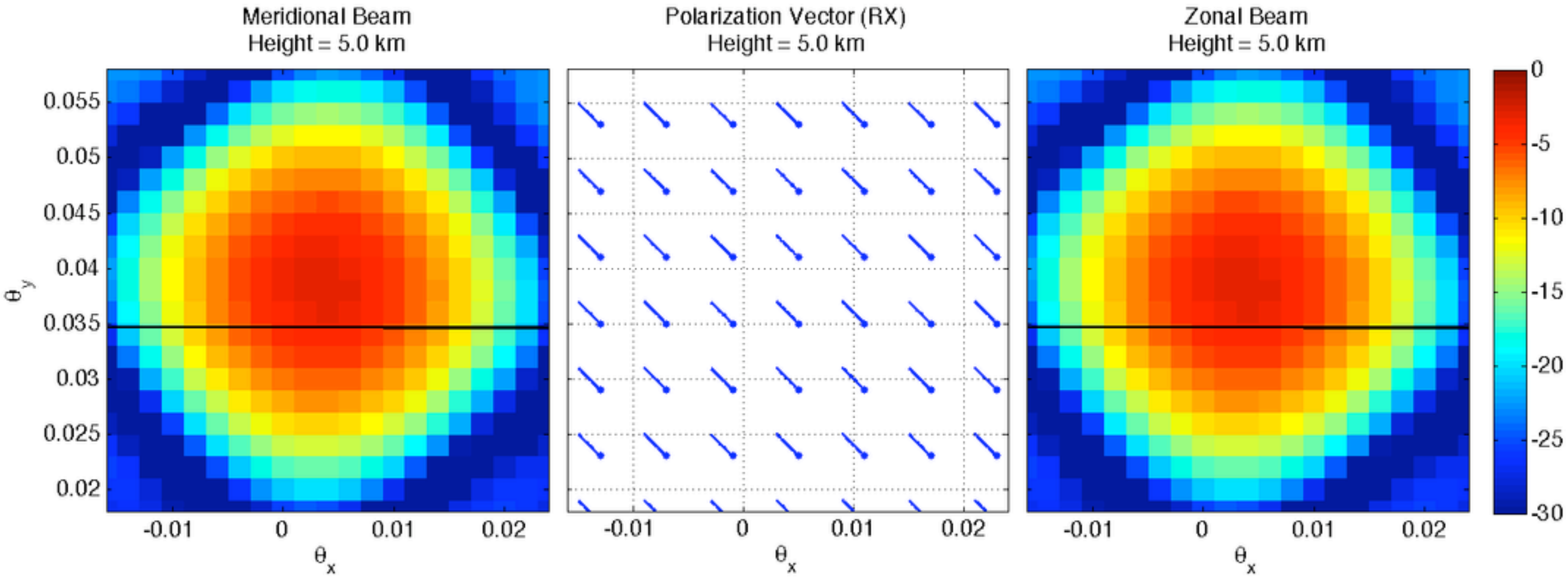


Comparisons between the Data and Model and some Conclusions

- Good agreement in the lower altitudes.
- Phase only matches at lower altitudes
- Different regimes of magneto-ionic propagation effects cause the beam pattern to change in altitude.



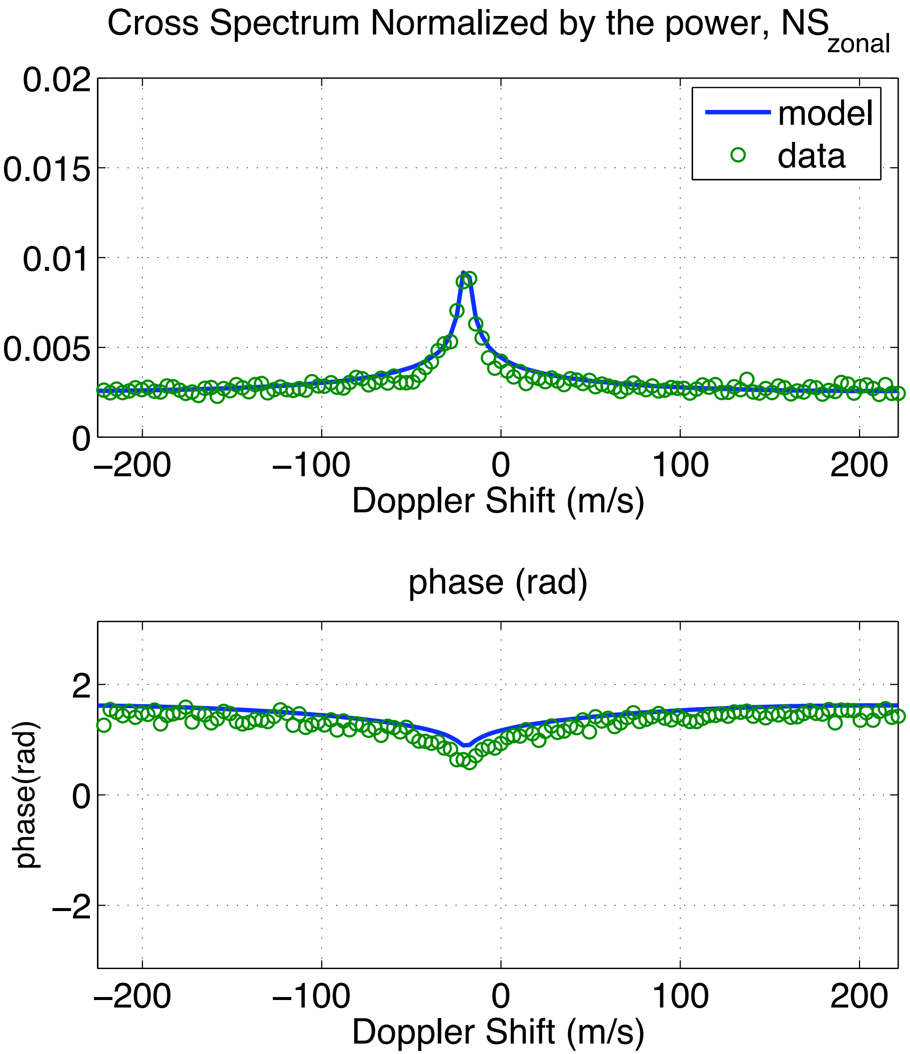
Magneto-ionic effects need to be taken into account



- Assuming a certain ionospheric density profile, and using the **differential phase method** we account for all the different regimes of magneto-ionic propagation effects.
- This effects cause the beam pattern to change in altitude.

Strategy for getting Temperatures

- From the differential phase method we calculate the electron densities.[Kudeki et al. 2003]
- So fixing the density, we fit the data to this spectral model in order to get one of the temperatures.
- Using the North - South interferometer we were expecting to estimate Te/Ti, but our first attempts are showing us that the dependence of Te/Ti is weak.



Conclusions and Future Work

- We have a spectral model that fits the data for reasonable temperatures.
- Need to include magneto-ionic effects to improve the forward model.
- Improving sensitivity on Te/Ti could be achieved by modifying the radar configuration. This would allow us to improve the Te/Ti sensitivity without loosing the accuracy of the ExB drifts estimation.

Thank you!