SuperDARN statistical characterization of magnetospheric regions for quasi real-time tracking

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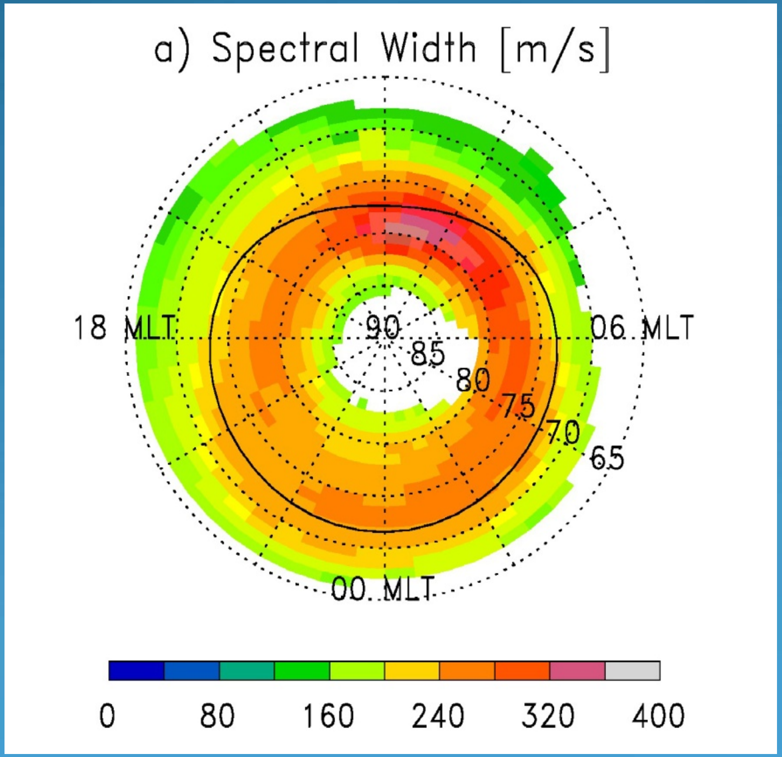
INTRODUCTION

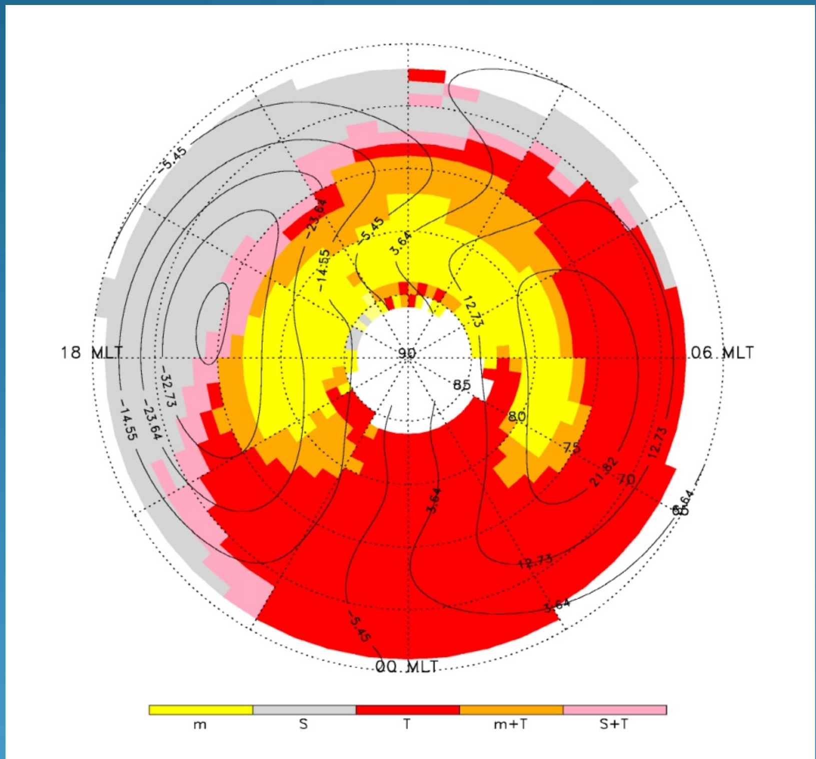
- SuperDARN backscatter properties have a clear dependence *versus* latitude and magnetic local time.

(Baker et al, 1995; Rodger et al, 1995; Dudeney et al, 1998; Chisham et al, 2004 ...)



- For example, the Doppler spectral width is a good estimator of Cusp location and of the Open-Closed field-lines boundary

- *R. André et al (2002)* : Introduction of a multivariate statistical method to classify regions with different backscatter properties *(Spectral width and standard deviation on phase and power)*.



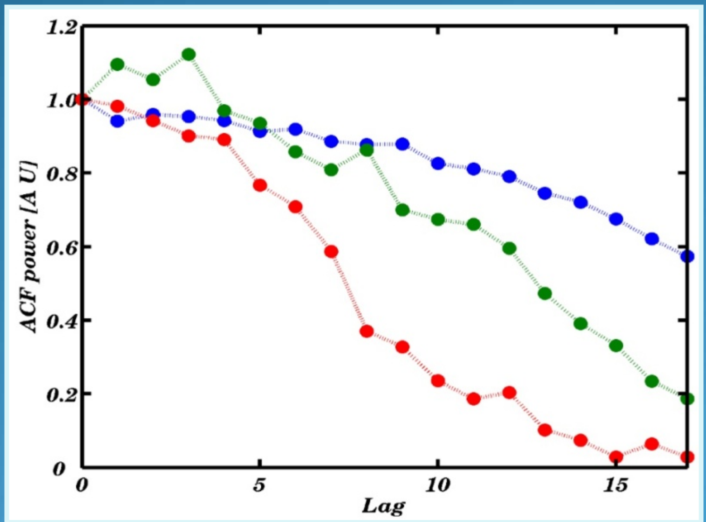
Class	Spectrum	Conditions
S	Narrow width, single component spectrum	Stnd. Dev. Phase < 0.30 Stnd. Dev. Pow. < 0.15 Width < 200 m/s
T	Large width, single component spectrum	Stnd. Dev. Phase < 0.30 Stnd. Dev. Pow. < 0.15 Width > 200 m/s
m	Multi-component spectrum	Stnd. Dev. Phase > 0.30 Stnd. Dev. Pow. > 0.15 Width > 200 m/s

Opens the perspective to monitor magnetospheric boundaries in near real time.

• Design a statistical model to classify ionospheric regions with different backscatter properties and identify the footprint of magnetospheric boundaries.

• Work directly on raw data.

• Perspective of quasi real-time operations.



Characterize the modulus of the ACF.

empirical model

Singular Value Decomposition

parametric model

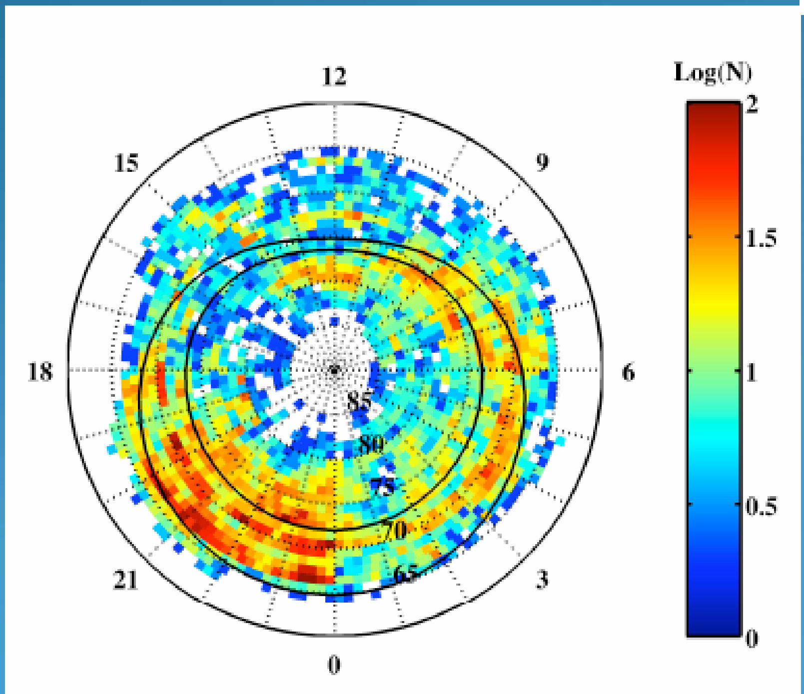
FitACF algorithm

Singular Value Decomposition

- SVD is a data reduction tool.
- It is applied on ACF modulus :

$$|R(t,\tau)| = \sum_{\alpha=1}^{18} \lambda_\alpha \cdot f_\alpha(t) \cdot g_\alpha(\tau) \ ,$$

$$\text{avec} \ \ \langle f_\alpha(t), f_\beta(t)\rangle = \langle g_\alpha(\tau), g_\beta(\tau)\rangle \begin{cases} 0 & \text{si } \alpha \neq \beta \ , \\ 1 & \text{si } \alpha = \beta \ . \end{cases}$$

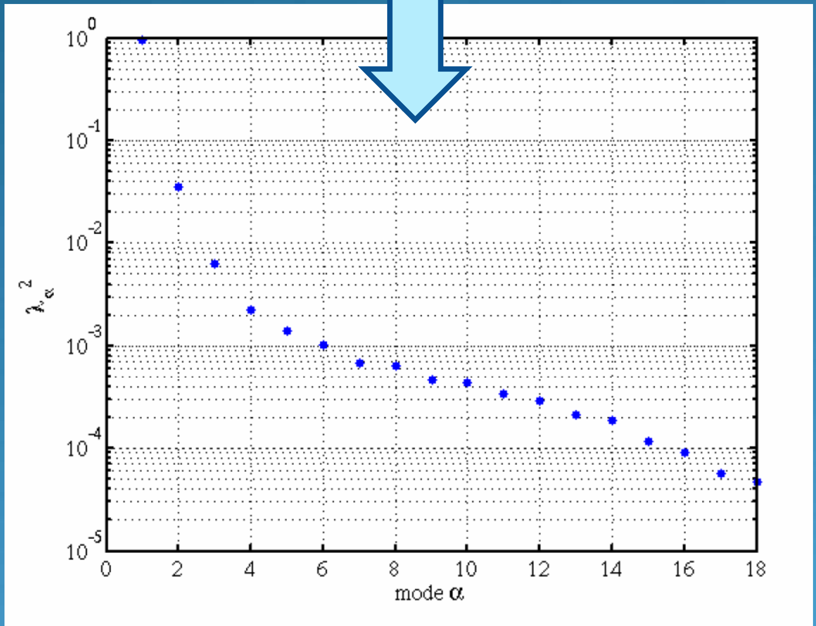


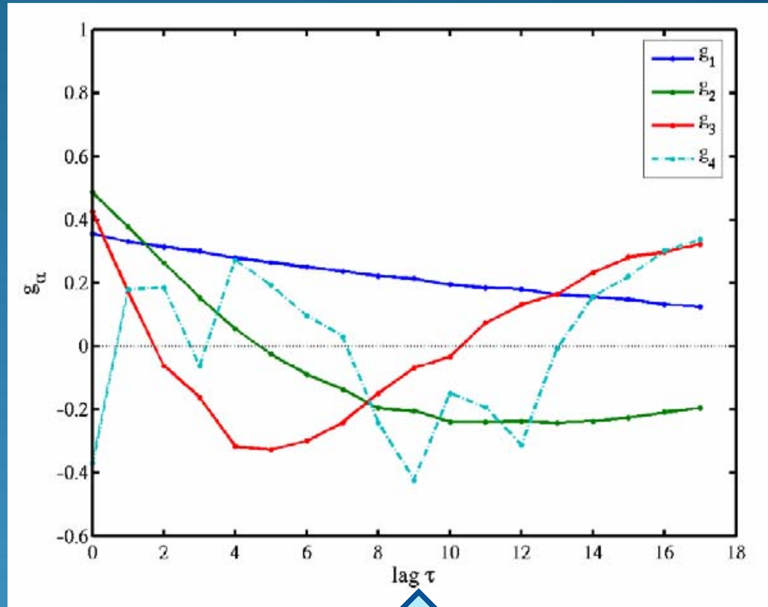
- $g_\alpha(\tau)$ base functions (modes)
- $f_\alpha(t)$ contribution of modes to ACF
- λ_α power of mode for describing ACF

Performed on ACF database without normalization
(4 days, quiet period, NH radars
 -> 22 000 ACFs)

SVD applied on the ACF power

First 3 modes describe 99.2% of total variance

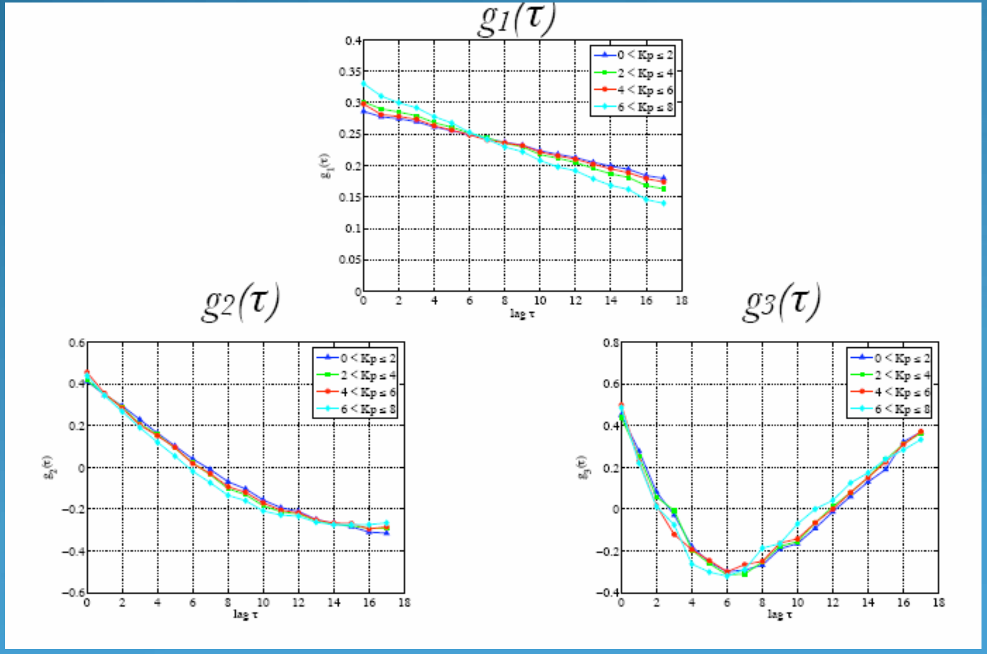


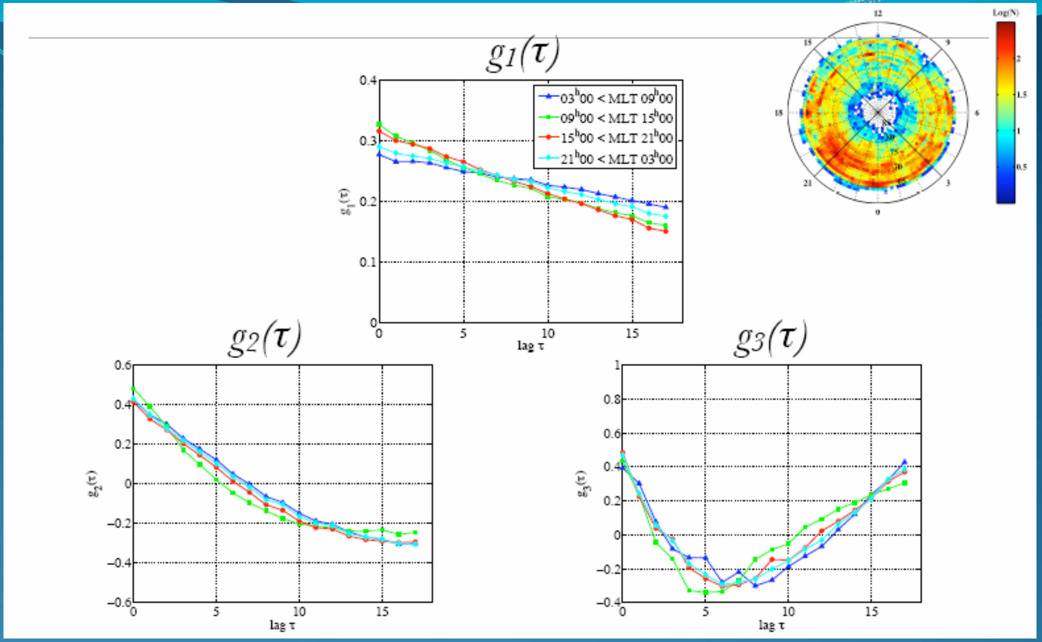


- Characterization of ACFs with only 3 parameters
- Weight coefficients F_i

The salient features of all ACFs are reconstructed by a linear combination of the first three modes.

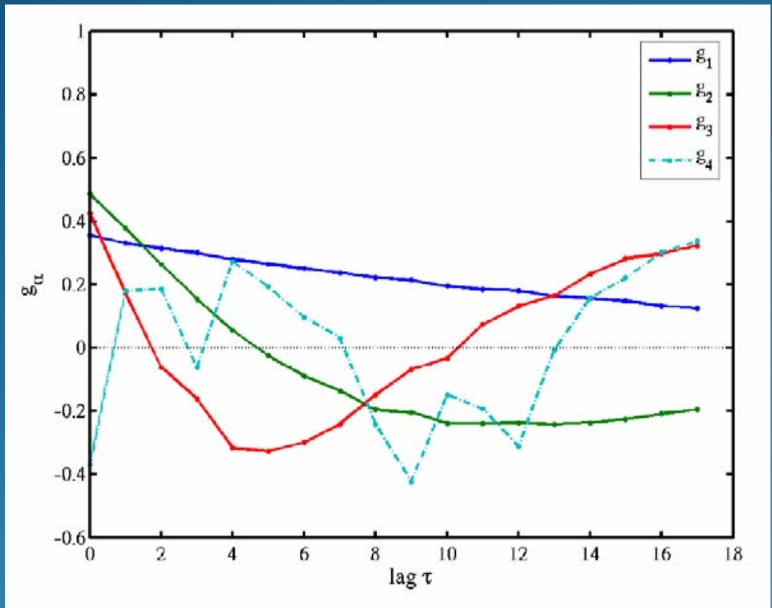
Influence of magnetic activity



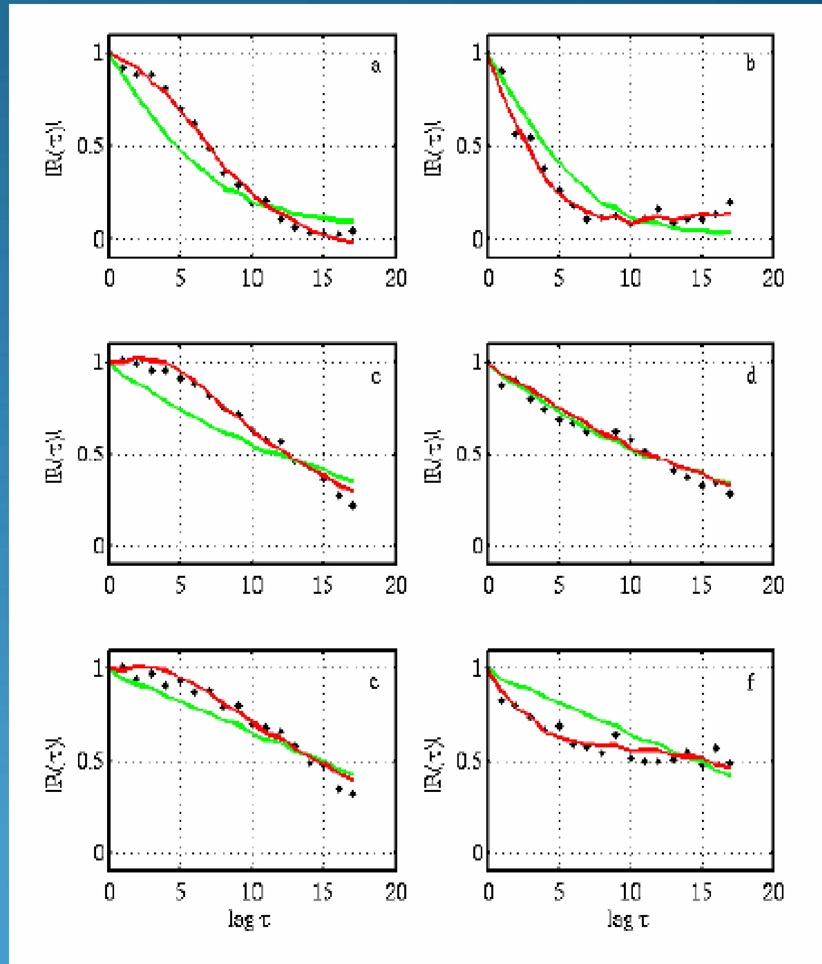


Influence of MLT sector

Reconstruction of ACFs

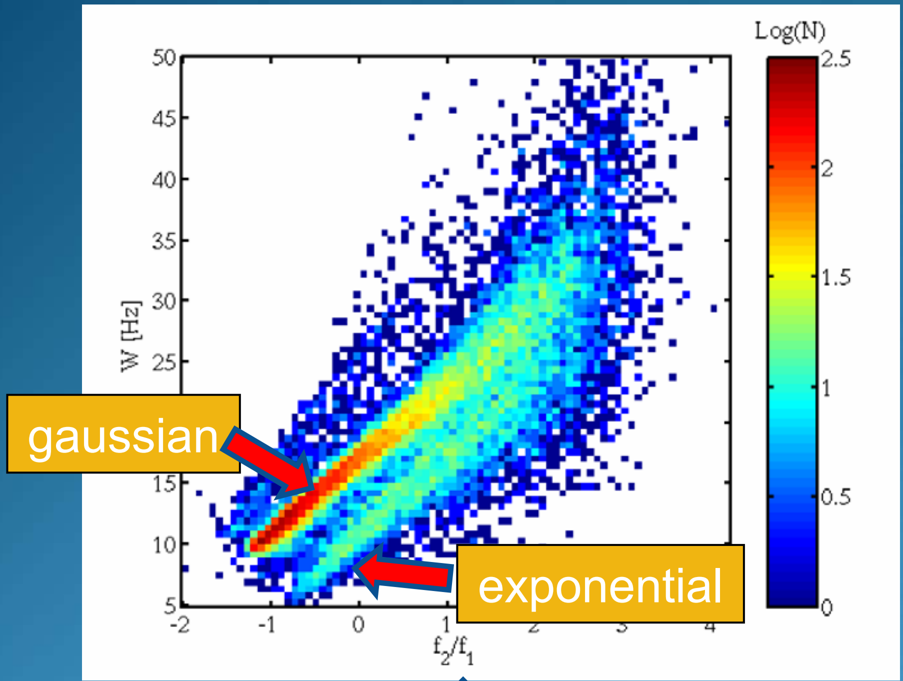


$$\hat{R}(t,\tau) = \lambda_1 f_1(t) g_1(\tau) + \lambda_2 f_2(t) g_2(\tau) + \lambda_3 f_3(t) g_3(\tau)$$

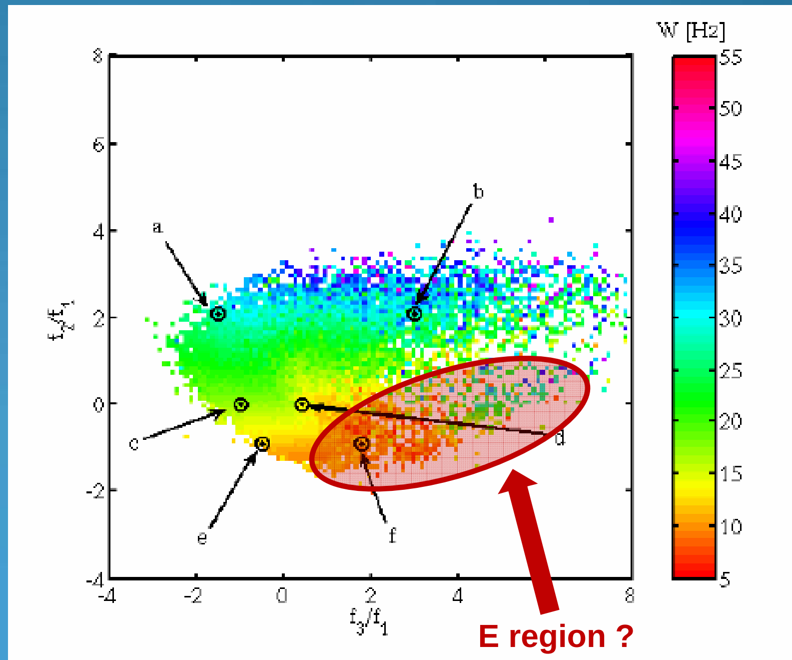


Interpretation of the 3 projections of each ACF in terms of physical quantities ?

Comparison with FitACF Algorithm

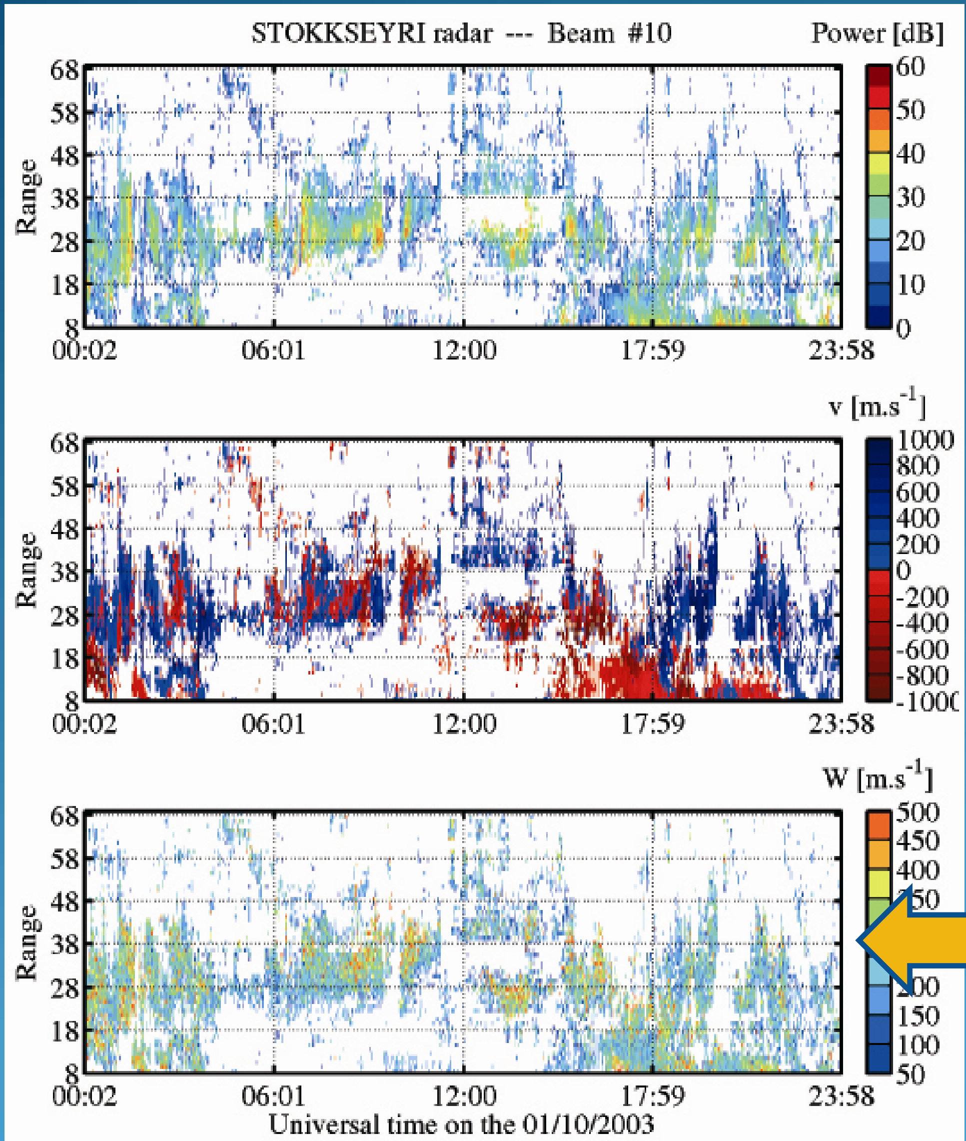


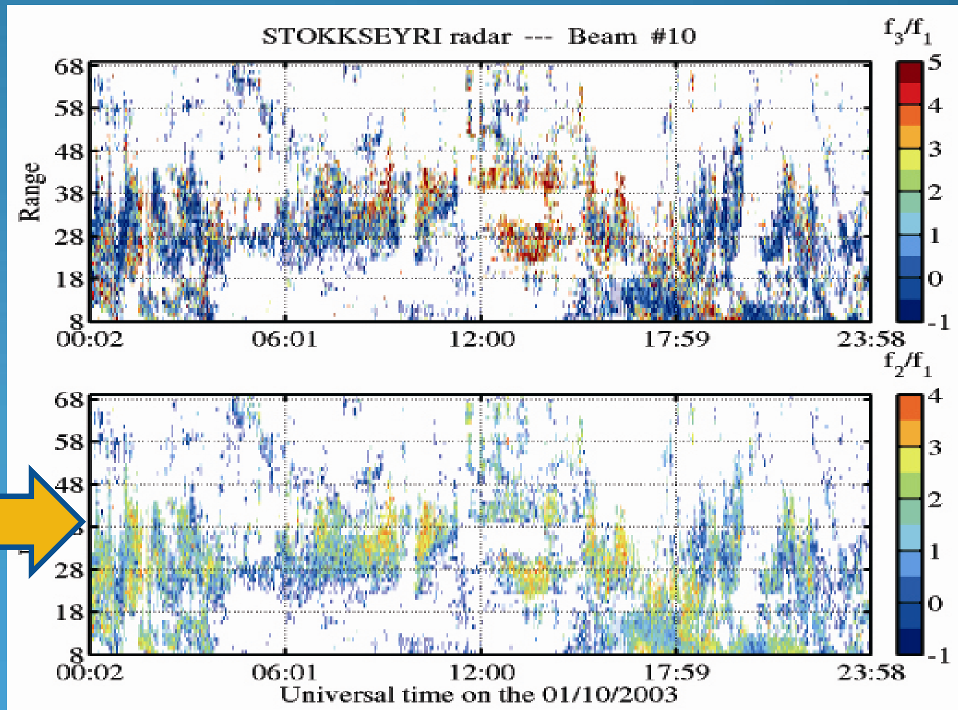
- No clear relation between f_3/f_1 and spectral width



- Clear connection between f_2/f_1 and Doppler spectral width
- Two ridges corresponding to gaussian and lorentzian models with FitACF

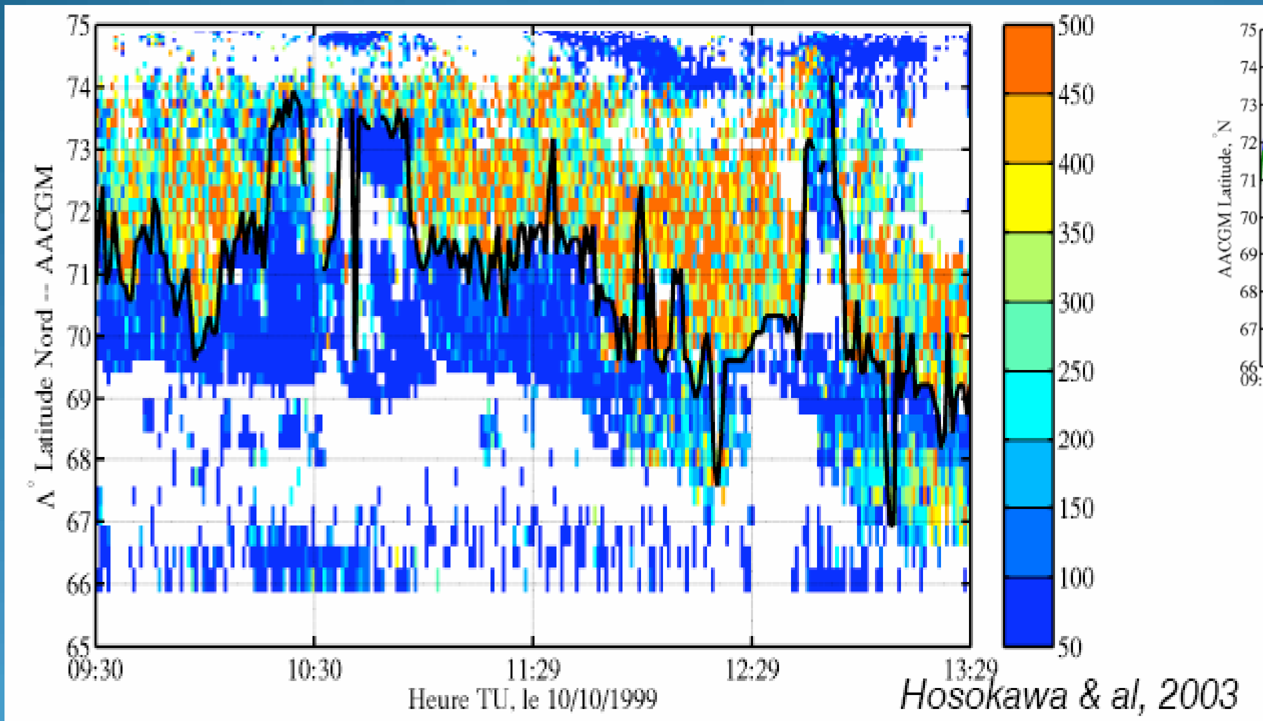
Comparison with FitACF Algorithm



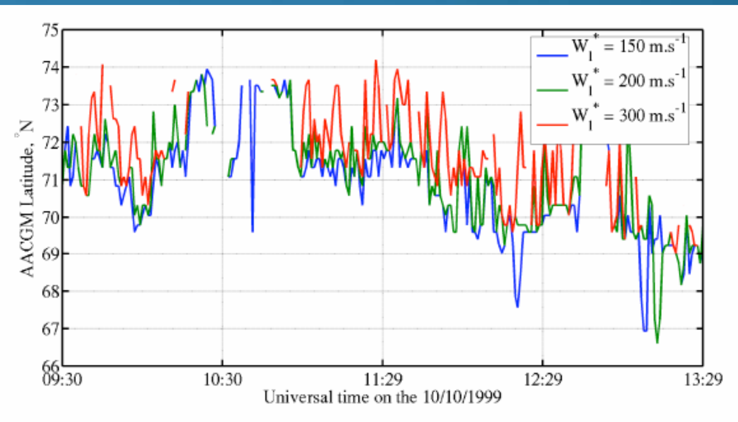


Characterization of OCB (Open – Closed field lines Boundary)

- Associated to spectral width boundary observed with SuperDARN radars



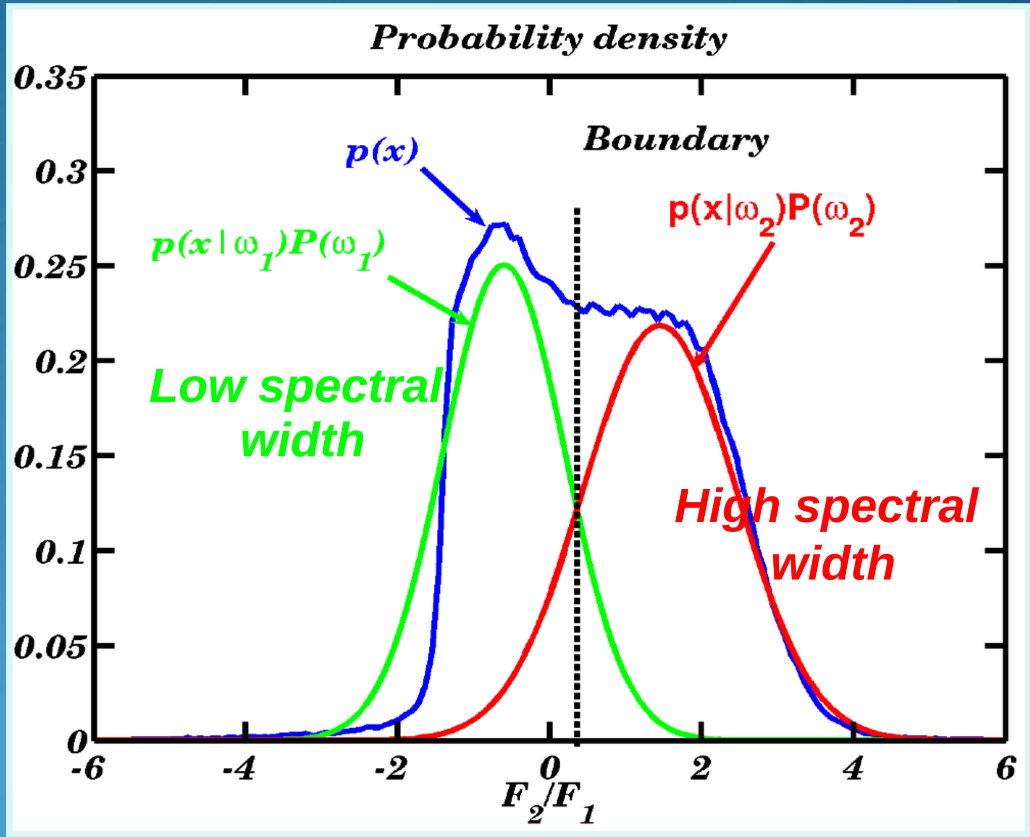
Hosokawa & al, 2003



- Location of OCB varies with spectral width velocity threshold
- Objective method ?

Identification of low-high Spectral Width Boundary
Bayesian Decision

- Superposition of 2 sets of parameters
- Difficulties to define a boundary.
- Need of an objective statistical criterion to fix rigorously the SWB.



Bayes Formula :

$$P(\omega_j|x) = \frac{p(x|\omega_j)P(\omega_j)}{p(x)}$$

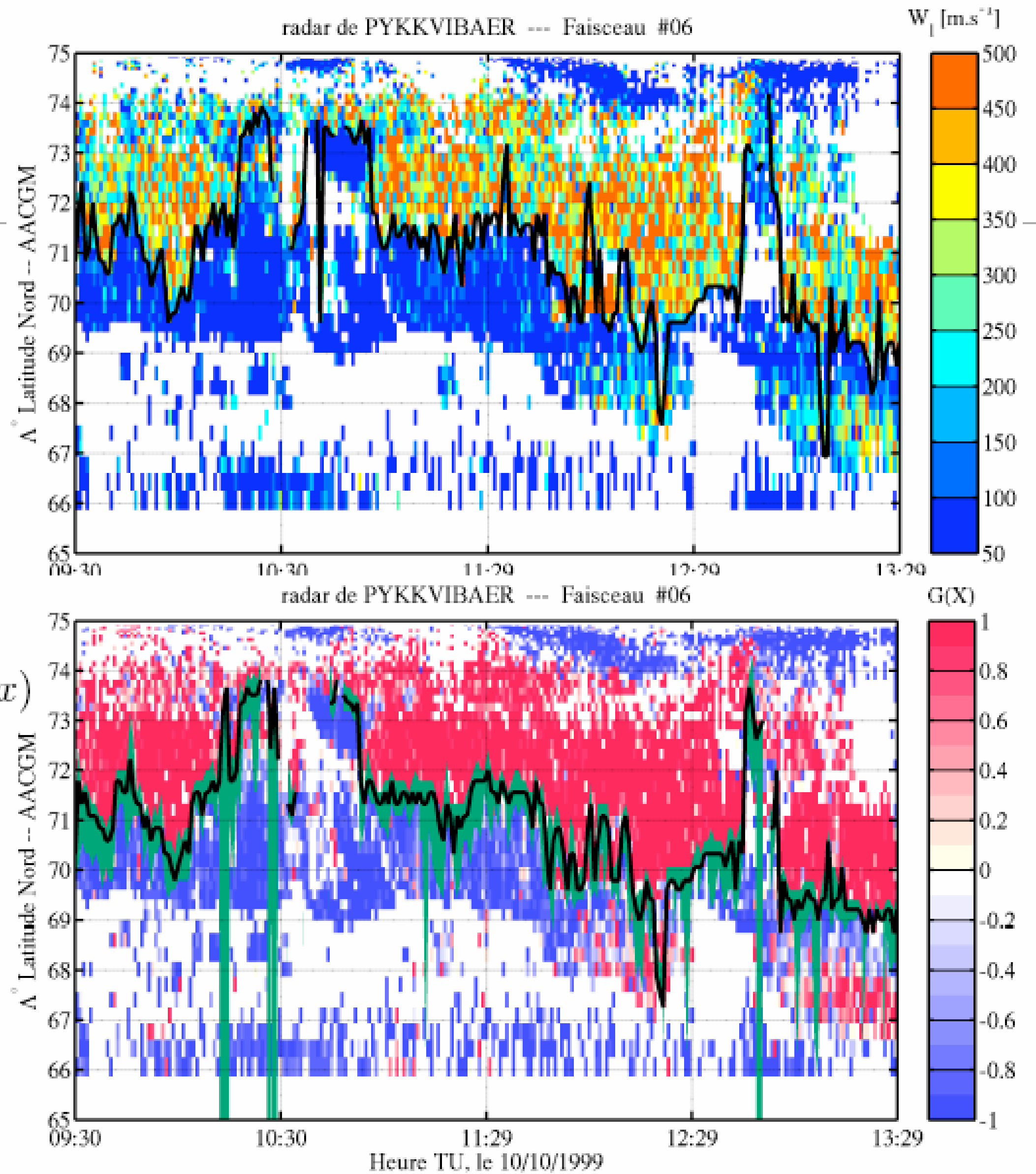
Where in the case of two categories :

$$p(x) = \sum_{j=1}^{2} p(x|\omega_j)P(\omega_j)$$

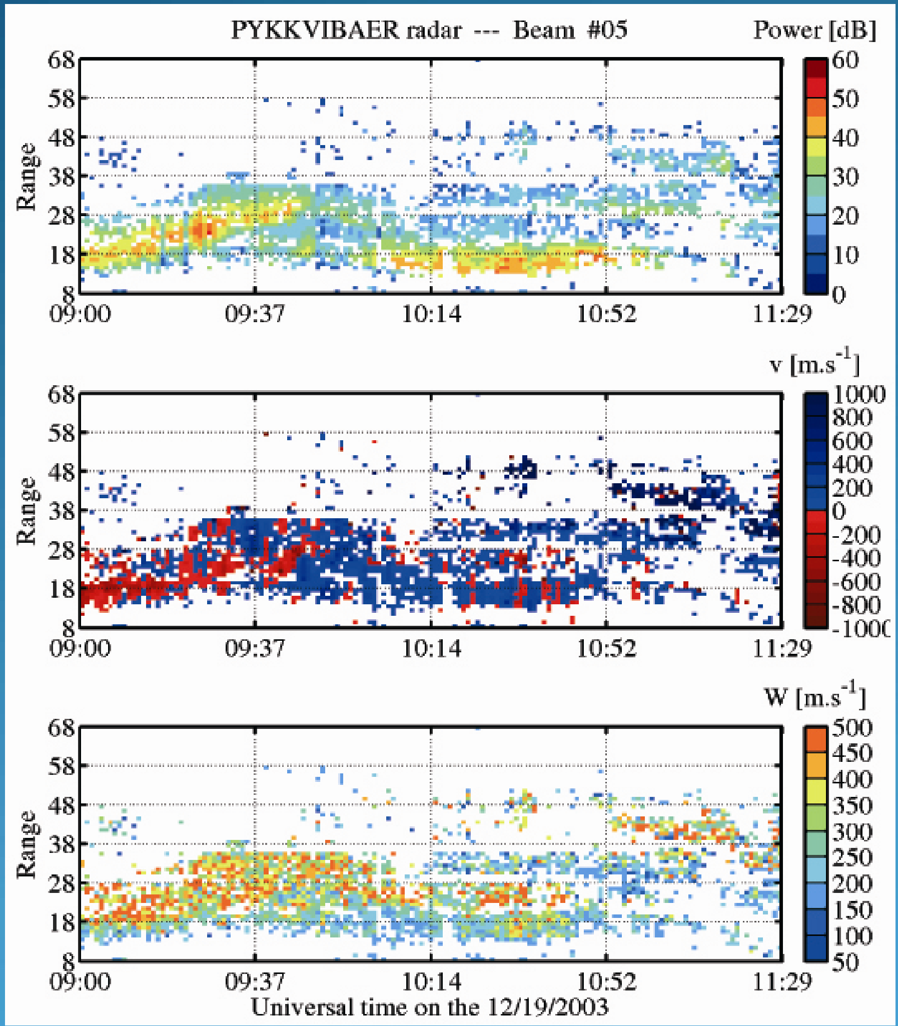
Pattern Classification
R. O. Duda, P. E. Hart and D. G. Stork

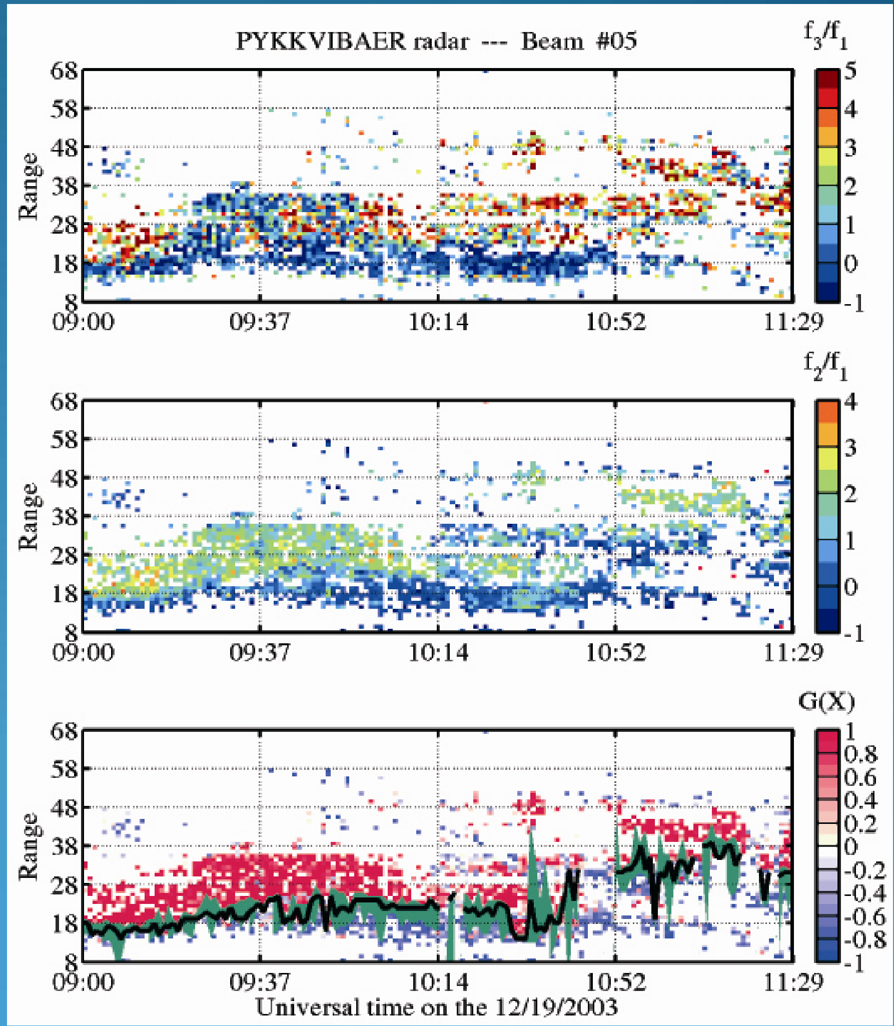
$W_l^* = 150\ m.s^{-1}$

$$G(x) = P(\omega_2|x) - P(\omega_1|x)$$



Identification of low-high Spectral Width Boundary
Example





Conclusion

- Possibility of detecting boundaries using only statistical properties of backscatter echoes (model independent).
- All ACFs can be reconstructed by linear combination of a few (3) modes
- The Spectral Width Boundary (SWB) can be located from theses modes (f2/f1 ratio)
- Physical meaning of f3/f1 ?
  - Help in discriminating E-region echoes ?
  - Shift in latitude of boundary (vs f2/f1 boundary). OCB vs SWB ?

- Use of phase information does not improve the determination of boundaries