Monitoring Magnetospheric boundaries using the statistical properties of SuperDARN radars echoes

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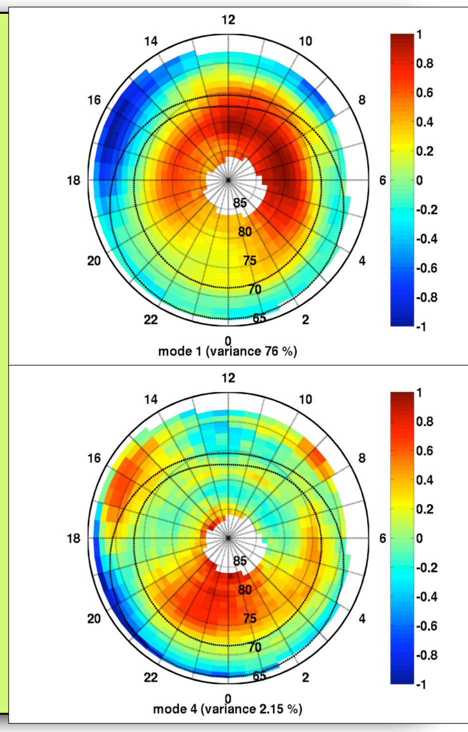
Justification and Motivation :

• Several studies of the SuperDARN radars have revealed a dependence between the statistical properties of the radar echoes and the ionospheric footprint of magnetospheric boundaries (esp. Auroral oval).

***Our objective** : Detect and Monitor magnetospheric boundaries in real time.*

• Application of the Singular Value decomposition (SVD) method (see lower right hand panel) by R. André & T. Dudok de Wit (2002) to fitted data revealed the possiblity to characterise different boundaries (see pictures right) based only on key parameters such as the spectral width.

• In order to monitor in real time, we propose to apply this approach directly to the raw data (Complex Autocorrelation Function - CAF) instead of the more usual physical parameters which require specific modelling.



Two statistical modes inferred by SVD from the radars echoes, during quiet conditions. Coordinates are magnetic local time and geomagnetic latitude.

The boundaries of the auroral oval are shown.

Characterization of the CAF component

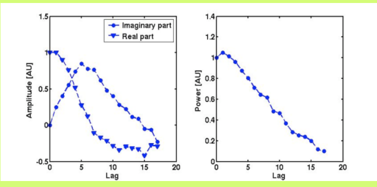


Figure (a)

We take a case study based on a sample covering four days of measurements, one day for each season.

We apply the Singular Value Decomposition to the modulus of the CAF (see *figure (a)* for an example of CAF). The CAFs are thereby decomposed into seperable functions of time, and time lag.

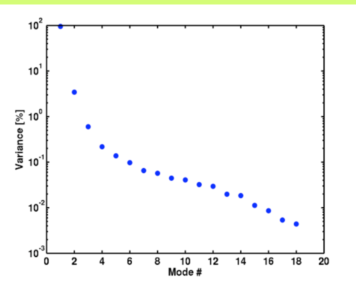


Figure (b)

- *Figure (b)* represents the weigths of 18 modes found with the SVD method.

Three modes stand out , *i.e* most of the variability is captured by three modes.

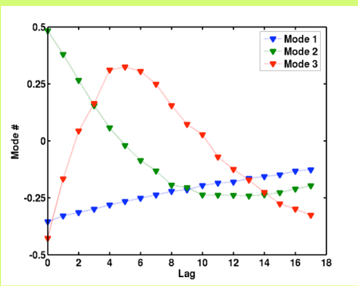


Figure (c)

- *Figure (c)* shows these 3 modes.

By linear combination of these three modes, we can reconstruct the salient features of all observed CAFs.

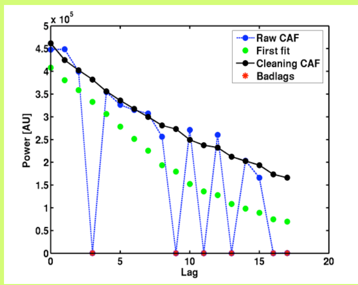


Figure (d)

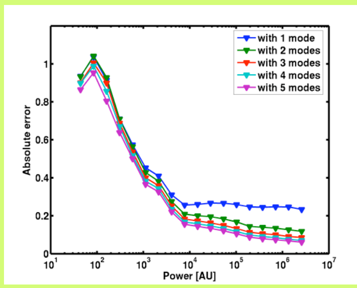


Figure (e)

The measured CAFs often contains invalid data (measurement errors).

- *Figure (d)* these can now be easily detected and interpolated.

- *Figure (e)* represents the evolution of the reconstruction error. Showing that below a CAF power of 8.10^3 *AU*, the variability cannot be reliably reconstructed anymore. The radars echoes are then too noisy.

Conclusion & Perspective

• Different statistical properties of the radar echoes coincide with the ionospheric footprint of different magnetospheric boundaries.

• Owing to the redundacy of the shape of the CAFs, the latter can be fitted By a linear combination of 3 modes only.

• As a by product : bad data in the CAFs can now be corrected more easily.

• Next step : use these 3 modes to perform real-time classification of the CAFs and thereby locate magnetospheric boundaries.

Singular Value Decomposition

Our database is an two-dimensional array. The first dimension represent the sample number of the CAF (*i.e* one event *i*) and the second dimension is the time lag.

The SVD decomposes this array into a set of separable modes. In doing so, it concentrates the salient features into the first modes, *i.e* those that have the largest weights w_k.

$$A(i,\tau) = \sum_k w_k f_k(i) g_k(\tau)$$

$$< f_k, f_l > = < g_k, g_l > = \delta_{kl}$$

- The f and g modes are orthogonal.