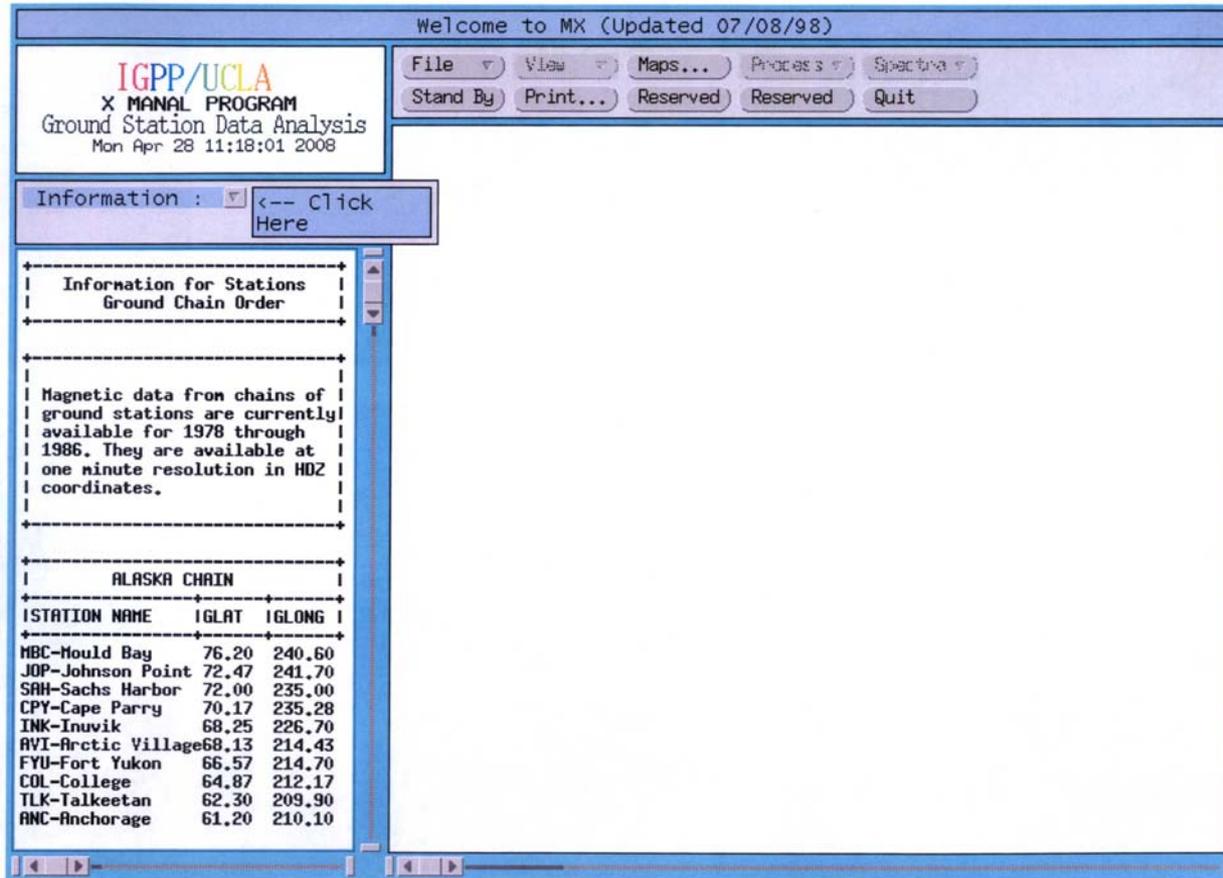


ESS 265
Introduction to Mx and Dynamic
Spectral Analysis

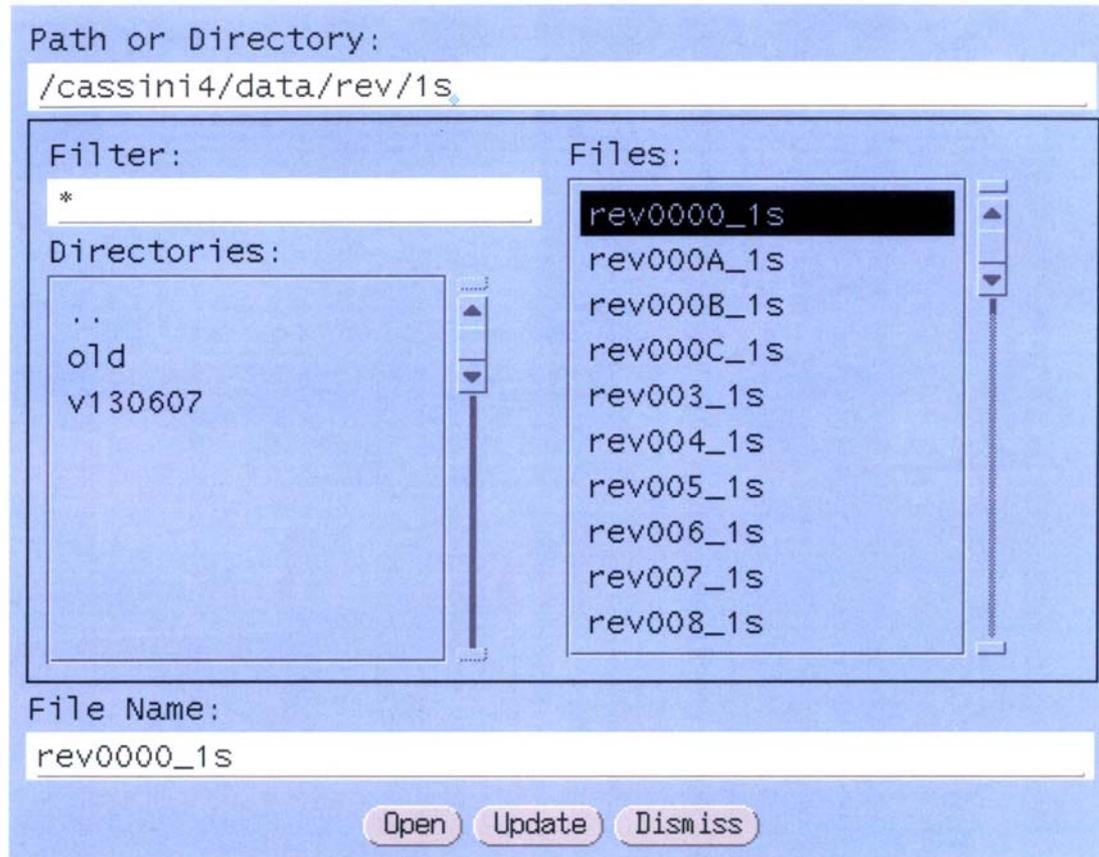
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April 30, 2008

Mx – Dynamic Spectral Analysis



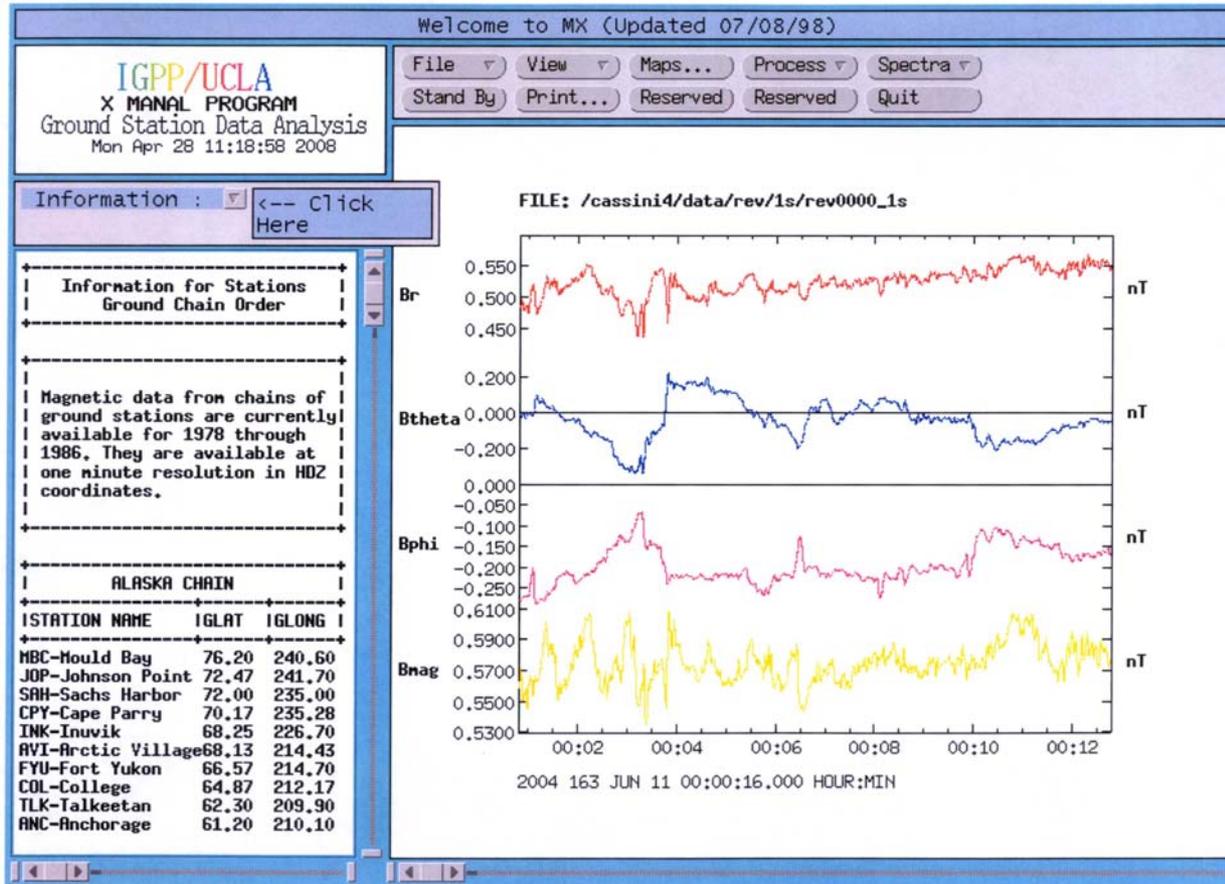
- Mx is designed to examine multiple magnetic field data sets.
- It combines capabilities for studying ground-based arrays and for studying dynamic spectra of varying wave properties.
- First, we need to obtain a file of data to analyze.

Data Files



- For this exercise, we examine a file of Cassini magnetometer data from the initial passage of Cassini through the Saturn magnetosphere. These data were acquired just hours after Cassini fired its engine.
- The data are on the cassini4 disk in the data directory of full rev files at 1s resolution. 3

Initial Data View



- The program shows the first data in the file. Use the slider bar to reach approximately the part of the file you wish to examine.
- Then use the View pull-down menu and the second option to do fine-scale positioning.

Time Selection

TIME SCALE SELECTION

File Start: 2004 163 JUN 11 00:00:48.000	File Stop : 2004 240 AUG 27 23:59:32.000
Plot Start: 2004 183 JUL 1 06:15:00.000	Plot Stop : 2004 183 JUL 1 06:45:00.000

Increase Decrease Increase Decrease

Year Mon Day Hour Min Sec Msec Year Mon Day Hour Min Sec Msec

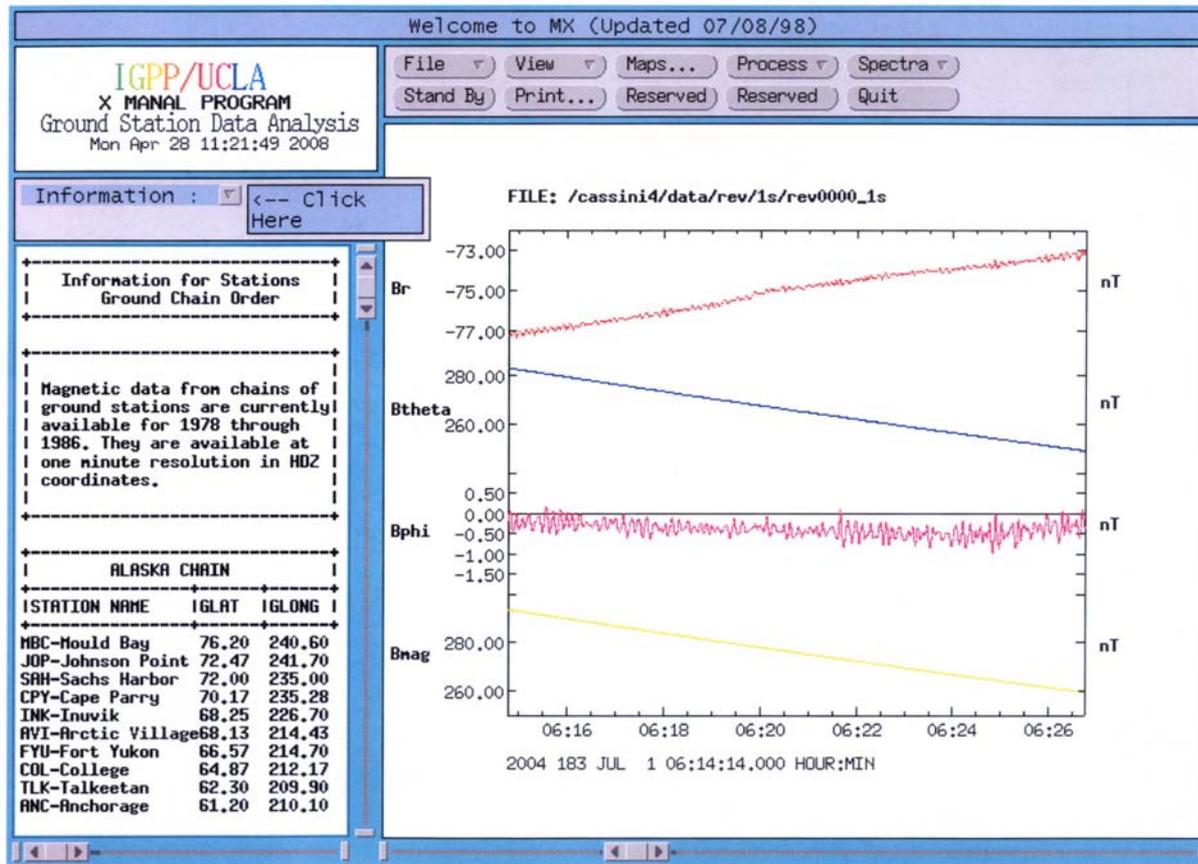
Y SCALE SELECTION

Y Rescale Method: <input checked="" type="radio"/> Automatic <input type="radio"/> Manual
Trace 1 - Minimum <u>-78.00</u> Maximum <u>-72.00</u> Tic Value <u>2.00</u>
Trace 2 - Minimum <u>240.00</u> Maximum <u>290.00</u> Tic Value <u>20.00</u>
Trace 3 - Minimum <u>-2.00</u> Maximum <u>1.00</u> Tic Value <u>0.50</u>
Trace 4 - Minimum <u>250.00</u> Maximum <u>300.00</u> Tic Value <u>20.00</u>

Time Scale Apply Vertical Scale Apply Dismiss

- Use the Increase and Decrease buttons to move the time series forward or backward.
- The time units can be clicked repeatedly to step through the data.
- The lower part of the box can be used to adjust the plots vertically.

Detrending Data



- Often, the motion of the spacecraft through a planetary magnetosphere creates a trend that will add power to a spectrum that is not really present.
- This occurs because Fourier analysis assumes that the signal repeats forever both before and after the period in question. This turns a smooth line into a saw tooth.
- Detrending removes the smooth variation, leaving only the waves.

Detrending Continued

The screenshot shows a software dialog box titled "Reset". Inside, there is a section for "Process Selection:" with five options: "F Filter", "R Rotation", "D Detrend", "D Derivative", and "D Deglitch". A note below these options states "Derivative and Detrend options are mutually exclusive." Below this is a "Process Sequence:" section with five buttons: "Detrend", "No-Op", "No-Op", "No-Op", and "No-Op". The "Detrend" button is highlighted with a thick border. At the bottom of the dialog are "Apply" and "Dismiss" buttons.

- Select the Process option and click on Detrend. Then press Apply.
- You then have options on how you wish you detrend.

Detrending Concluded

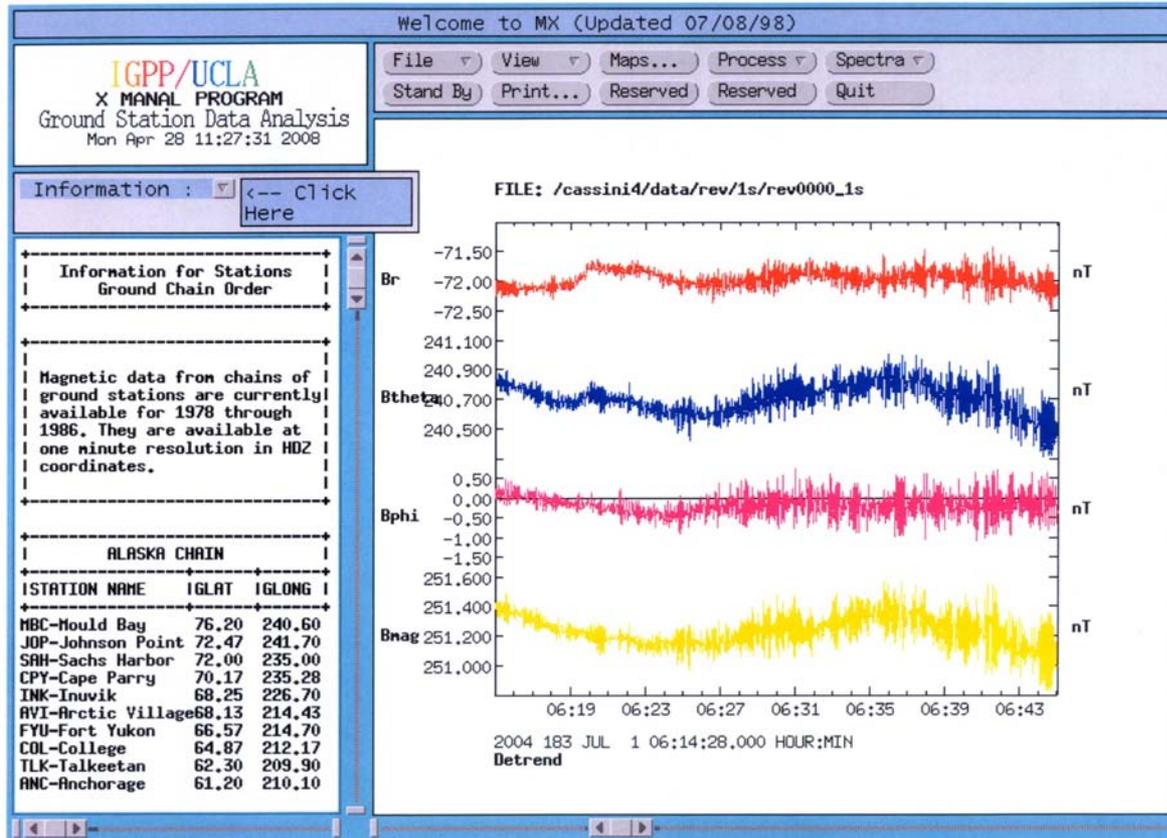
detrendMethod Linear Quadratic Bypass Toggle: Remove Average

DETREND PARAMETERS

YZEROR(1)= -76.978	SLOPE(1)=	+0.006	DSLOP(1)=	-0.000	BASE(1)=	-71.974
YZEROR(2)= +282.445	SLOPE(2)=	-0.051	DSLOP(2)=	+0.000	BASE(2)=	+240.865
YZEROR(3)= -0.541	SLOPE(3)=	+0.001	DSLOP(3)=	-0.000	BASE(3)=	-0.197
YZEROR(4)= +292.743	SLOPE(4)=	-0.050	DSLOP(4)=	+0.000	BASE(4)=	+251.391

- A sufficiently short interval can be detrended linearly, but if the spacecraft goes far during the analysis interval, the data may need to be detrended quadratically.
- If you are going to relate the analysis to the background magnetic field, say to find left-hand and right-hand waves, then you do not wish to remove the average field value.

Dynamic Spectral Analysis



- Dynamic spectra are used to follow temporal changes in a signal, for example, the change in frequency of waves at different radial distance, or amplitude changes or directional changes, etc.
- We proceed by slicing the time series into short segments of time and calculating Fast Fourier Transforms over these segments, move a fraction of the length of the segment and repeat and repeat until one reaches the end of the time interval.

Control of the Dynamic Spectral Analysis

The screenshot displays a software interface for dynamic spectral analysis with the following sections and controls:

- Current Time series Information:**
 - Data Resolution: 1.000 Second
 - Record Number: 1801
 - Time Domain: 1800.000 Second
- Fast Fourier Transform Parameters:**
 - FFT Data Points: 256 (# points)
 - FFT Interval Shift: 64 (# points)
 - FFT Bandwidth: 11 (odd #)
 - Whitening Factor: 0.000 (>= 0.0)
 - Time domain Avg: 1.000 (# points)
 - Delta t: 1.000 Seconds
- Sum of Power Spectra:**
 - Options: Px + Py + Pz, Px + Py + Pz - Pt
 - Normalized:
 - Ion Gyro: N: 16
 - Trace Color: Black White
- Dynamic Spectra Format:**
 - Power Spec Min: -2, Power Spec Max: 0
 - Coherence Min: 0.0, Coherence Max: 0.8
 - Angle Minimum: 90, Angle Maximum: 90
 - PowerA: 1 2 3 4, Frequency: Linear Logarithm
 - PowerB: 1 2 3 4, GrayScale Max: Black White
- Coherence/Phase Specification:**
 - Coherence Unmask min: 0.0, Coherence Unmask max: 1.0
- Dynamic Spectra Window Size:**
 - Window Horizontal Size: 400 to 1100
 - Window Vertical Size: 400 to 800
- Bottom Navigation:** Power A, Power B, Coherence, A/B Ratio, Phase, Wave Analysis, Dismiss
- Status Bar:** Dynamic Spectra Menu Selections :::::

- After selecting the Dynamic Spectra option, the program allows you to adjust its default settings.
- The number of points in each spectrum, say 256, determines the frequency range of the analysis and the frequency resolution. The shift determines the pixel size of the analysis segments. This smoothes the results in time.
- The bandwidth smoothes in the frequency direction.

Control of Dynamic Spectral Analysis

Current Time series Information:
Data Resolution: 1.000 Second Record Number: 1801
Time Domain: 1800.000 Second

Fast Fourier Transform Parameters:
FFT Data Points: 256 (# points)
FFT Interval Shift: 64 (# points)
FFT Bandwidth: 11 (odd #)
Whitening Factor: 0.000 (>= 0.0)
Time domain Avg: 1.000 (# points)
Delta t : 1.000 Seconds

Sum of Power Spectra:
Px + Py + Pz
Px + Py + Pz - Pt
Normalized:
Ion Gyro: N: 16
Trace Color: Black White

Dynamic Spectra Format:
Power Spec Min. -2 Power Spec Max. 0
Coherence Min. 0.0 Coherence Max. 0.8
Angle Minimum 90 Angle Maximum 90
PowerA: 1 2 3 4 Frequency: Linear Logarithm
PowerB: 1 2 3 4 GrayScale Max: Black White

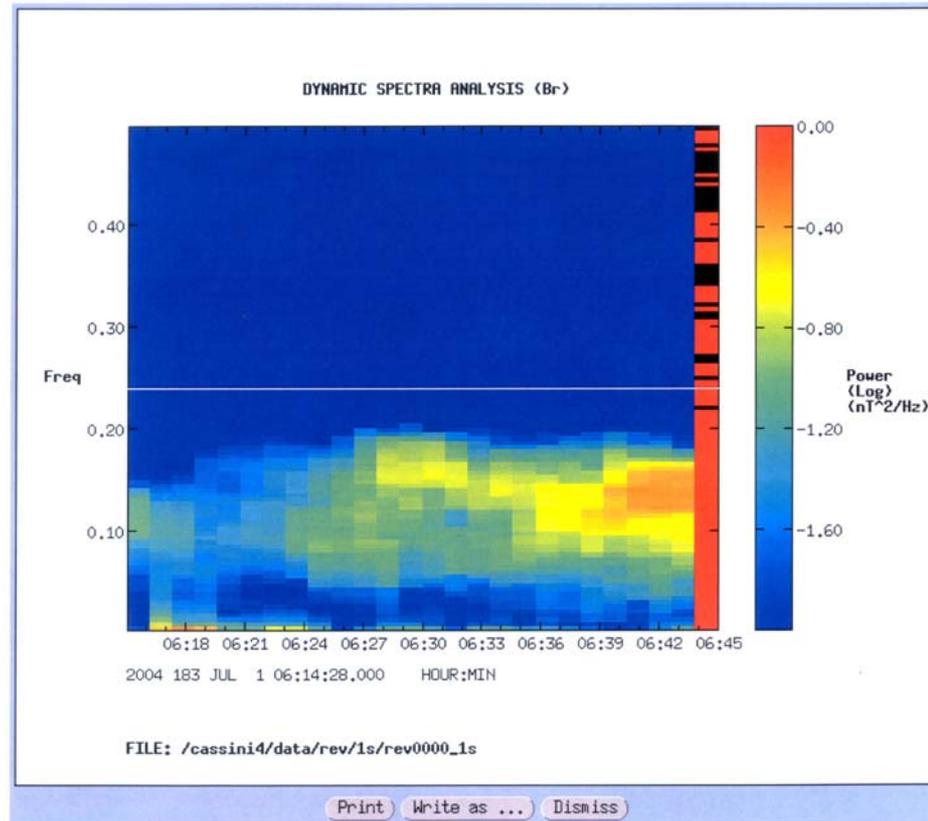
Coherence/Phase Specification:
Coherence Unmask min 0.0 Coherence Unmask max 1.0

Dynamic Spectra Window Size:
Window Horizontal Size: 400 1100
Window Vertical Size: 400 800

Power A Power B Coherence A/B Ratio Phase Wave Analysis Dismiss
Dynamic Spectra Menu Selections :::::

- The format box gives you control of the ranges of the color plot and what you are analyzing. You can Fourier analyze the first four quantities in your file.
- You can calculate the power in any of the four time series or the coherence between any two time series or the phase or the ratio of the power. These could be used for finding the resonant frequency of magnetospheric field lines in ground-based records, for example.

Dynamic Spectra



- Linear and logarithmic frequency axes are both available.
- You can draw a line at a frequency equal to the gyrofrequency of an ion. If you detrend the field, the gyrofrequency will be detrended, too.
- Sometimes artifacts appear in the last spectrum.
- This analysis is good for one or two component waves, but for three components, we need to use “wave analysis.”

Three-Dimensional Analysis

Data Information:

Data Resolution: 1.000 Second Record Number: 1801

Wave Analysis Results:

Power Spectra Trace	Compress Power	Scale: Linear
Transverse Power	Propagation Angle (BK)	
Propagation Angle(Means)	Ellipticity(Born-Wolf)	
Ellipticity(Means)	Azimuth Angle	

Frequency Range for 2-D:

Start Freq.: 0.004 Stop Freq. 0.496

Coherence Mask:

Coherence Mask Disabled
N/A
N/A

Analysis 3-D Analysis 2-D Dismiss

K=1,2,...(N-1)/2 (N:Odd) or N/2 -1 (N:Even). Where N is the FFT Data Points as above, Frequency=K/(N*dt), dt is the data resolution.

- In the bx program, you may select a frequency range and find the in-phase and quadrature phase cross spectral matrices. From this, you can do minimum variance analysis and get the direction of minimum variance. You can also get the propagation direction and ellipticity from the quaspectrum.
- The program also allows the user to block out (mask) the spectrum when the coherence between any two parameters is low.