Propagation Analysis of STAFF-SA Data with Coherency Tests (A User's Guide to PRASSADCO)

Ondřej Santolík

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LABORATOIRE DE PHYSIQUE ET CHIMIE DE L'ENVIRONNEMENT
Centre National de la Recherche Scientifique

3A, Avenue de la Recherche Scientifique - 45071 ORLEANS Cédex 2
Téléphone: (33) (0)2.38.25.52.64 - Télécopie/Fax (33) (0)2.38.63.12.34

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Auteur / Author : Ondřej Santolík

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RESUMÉ :

Ce document contient la description du programme PRASSADCO. Le logiciel est destiné à l'analyse des mesures de plusieurs composantes d'ondes électromagnétiques. Il comprend différentes méthodes pour estimer les paramètres de polarisation et de propagation, par exemple la direction du vecteur d'onde, le vecteur Poynting et l'indice de réfraction. On a plusieurs possibilités pour représenter les résultats dans une forme graphique ou numérique. L'application principale de ce logiciel est l'analyse de données de l'expérience STAFF-SA à bord des satellites Cluster.

ABSTRACT :

This report contains a user's guide to the computer program PRASSADCO. The program is designed to analyze multicomponent measurements of electromagnetic waves. It implements a number of methods used to estimate polarization and propagation parameters, such as the wave vector direction, the Poynting vector, and the refractive index. The results may be represented in several visual and numerical formats. The principal application is the analysis of data recorded by the STAFF-SA instruments onboard the Cluster satellites.

Visa de relecture / referees	**Nom / name**	**Date**	**Signature**
Scientifique	M. Parrot		
Documentaliste LPCE	M. Schillewaert		

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1. Introduction

PRASSADCO (*PR*opagation *A*nalysis of *S*TAFF-*SA D*ata with *CO*herency tests) is a computer program which calculates characteristics of electromagnetic waves from measurements of their electric and magnetic fields.

The main purpose of PRASSADCO is to facilitate scientific analysis of data obtained by the STAFF-SA devices (spatio-temporal analysis of field fluctuations, spectrum analyzer) on board the four satellites of the Cluster mission [*Cornilleau-Wehrlin et al.,* 1997]. The program can however process arbitrary data containing thee-axial measurements of the magnetic field fluctuations. Tests have been made with simulated data as well as with the received data of STAFF-SA. The program was also used to process the data of the MEMO (Interball) and HFWR (Polar) instruments.

Data processing is done in the frequency domain, and a previous spectral analysis of multicomponent measurements is supposed. The program is designed to produce both preview and publication-quality figures in different formats and/or to store the results in a numerical form.

This document is intended to serve as a guide for users of PRASSADCO. Section 2 describes the input data, Section 3 shows how to run the program, Section 4 defines all available data types and processing methods, and Section 5 describes the output. The description of the processing chain for the STAFF-SA data can be found in Section 6. In Section 7 the user will find a detailed reference to the control data. Appendix shows several examples demonstrating how to use the program.

For a quick reference to the processing of the STAFF-SA data the reader can directly skip to Section 6.

2. Input data

The input data are spectral matrices, directions of electric antennae, power-spectral densities, and auxiliary information. Their format is relatively general to accommodate different modes of experiment. All these data are stored in binary files which must by prepared by an instrument-specific procedure. For STAFF-SA, a procedure `read_N2SA` described in Section 6 is used.

Each data item contains the time of measurement, an elementary time interval defining the duration of data analysis, and an expected time interval to the next data. All time information is given in MJD (modified Julian date). Additionally, an elementary frequency interval is defined for each spectral matrix and for the power-spectral density data.

2.1. Spectral matrices

The spectral matrices result from processing of measured components of the wave electric and magnetic fields. Three orthogonal magnetic field components are required to determine the polarization, coherency and restricted propagation properties. PRASSADCO supposes that these data have been previously subjected to multicomponent spectral analysis resulting in Hermitian matrices of auto-power spectra and cross-power spectra. The coordinate system defined by the three magnetic components will be called the "basic coordinate system" in the following. Often (but not necessarily) this is a coordinate system whose z-axis is parallel to the anisotropy axis of the medium (direction of the ambient magnetic field $\vec{B}_0$). For STAFF-SA the transformation to this system is managed by the `read_N2SA` procedure (see Section 6.3).

2.2. Directions of electric antennae

With the magnetic field data the propagation direction cannot be fully determined. Two antiparallel directions are not distinguished. At least one additional electric antenna is necessary to estimate the propagation direction without this ambiguity. However, this estimation has additional difficulties compared to the analysis of the magnetic field data. It is therefore reasonable to separately proceed with the magnetic part of the spectral matrix and to check the results. PRASSADCO involves methods to process the data of several electric antennae. They may have arbitrary (known) directions with respect to the "basic" frame. The directions of the two electric antennae used by STAFF-SA are stored by `read_N2SA` (see Section 6.3).

2.3. Power-spectral densities

Power-spectral densities contain essentially the same information as auto-power spectra in the spectral matrices. The difference is that they may be obtained by a different procedure. As a consequence they may have higher frequency resolution or higher time resolution. The latter is the case of the STAFF-SA data.

2.4. Auxiliary information

Auxiliary information can include any time-dependent data connected to the measurement (position, characteristic frequencies of the medium, ...). PRASSADCO may use this information to annotate figures, to plot it or to write it in output files. Auxiliary information saved by `read_N2SA` always contain the STAFF-SA mode of operation (see Sections 6.2 and 6.3). It can also include the vector of the DC magnetic field $\vec{B}_0$ read from primary parameter file of the FGM device [*Daly*, 1998], and all the information stored in a summary parameter file of auxiliary data described by *Daly* [1998] (e.g., the position of the Cluster satellites).

2.5. Control parameters

The control parameters define the way how the input data are processed by PRASSADCO. They are always read from a control file which contains an ASCII coded text. A detailed description of this file is given in Section 7. The user can modify the control file by a text editing tool and specify the control file name when calling PRASSADCO. Different control files can be stored for later use. Examples are given in the appendix (Figures 4, 6, 8, and 12). The control file can also be modified by another program (script) which subsequently runs PRASSADCO without any user intervention. For example this mode is used in the chain of basic STAFF-SA processing to plot the overview figures. This mode can also be used in possible web-based applications. The program in its present state is designed to the "interactive" work involving direct user modifications of the control file, and an effort has been made to handle possible errors made by user while creating the control file.

3. Running PRASSADCO

PRASSADCO is written in IDL (Interactive Data Language). This software must be accessible on the computer where PRASSADCO is run. The program further needs that the above described input data are ready and the control file is prepared. The user can then run PRASSADCO entering a command `pra` within the IDL environment or invoking the script `pra` which starts a special IDL session for a single run of PRASSADCO. In both cases the name of the control file can be passed to the program as a parameter. An example for a run within the IDL session:

```
IDL> pra,'control_file_name'
```

An example for a run from the script:

```
pra control_file_name
```

If the name of the control file is not defined, an implicit name `pra.ini` is assumed. Note that execution of the program within the IDL environment may be substantially faster (see item `REUSE` on page 7.2.1). Note also that the graphic output directed to the screen device (see Section 5) disappears when exiting the IDL session after running the program from the script `pra`.

The program always writes information about its run to the standard output. An example is given in Figure 1.

```
IDL> pra,'example1'
-------- PRASSADCO(2000Jun26) started Wed Jun 28 18:16:47 2000
   ...restoring data from /home/santolik/staff_sa/data/Co_991117_1_1a_sm.dat
 Spectral matrices of 5 components in 3872 time intervals and 27 frequency intervals.
   First time: 1999-11-17 10:35:14.608
   Last time:  1999-11-17 15:57:39.152
   First frequency: 8.00000 Hz
   Last frequency:  4096.00 Hz
 Directions of 2 electric antennae.
   ...restoring data from /home/santolik/staff_sa/data/Co_991117_1_1a_psd.dat
 Power-spectral density of 5 components.
   First time: 1999-11-17 10:35:14.608
   Last time:  1999-11-17 15:57:39.182
   First frequency: 8.00000 Hz
   Last frequency:  4096.00 Hz
   ...restoring data from /home/santolik/staff_sa/data/Co_991117_1_1a_aux.dat
 7 AUX tags   MODE XGSE YGSE ZGSE DC_BX DC_BY DC_BZ
 ----------------------------------------
Available Data Types:  B1 B2 B3 BSUM E1 E2 ESUM PSD_B1 PSD_B2 PSD_B3 PSD_BSUM
 PSD_E1 PSD_E2 PSD_ESUM ELL ELLSVD POLP POLS POLSVD THM THP THS THSVD THPOLSVD PHM
 PHP PHS PHSVD PHPOLSVD EIGEN EIGEN2 EIGEN3 EBPHASE1 EBPHASE2 PSIGN1&2 PSIGN1 PSIGN2
 PSIGNF1&2 REFR1&2 ISHIFT1&2 POYF1&2 THPOYF1&2 PHPOYF1&2 THSVDEF1&2 PHSVDEF1&2
 REFRSVDEF1&2 THSVDTF1&2 PHSVDTF1&2 REFRSVDTF1&2 ISHIFTSVDTF1&2 POLSVDTF1&2 ANTDIRX1
 ANTDIRY1 ANTDIRZ1 ANTDIRX2 ANTDIRY2 ANTDIRZ2 MODE XGSE YGSE ZGSE DC_BX DC_BY DC_BZ
 ----------------------------------------
   ...plotting bsum
   ...plotting thsvdtf
   ...plotting ANTDIRX1
-------- PRASSADCO(2000Jun26) done    Wed Jun 28 18:17:48 2000
IDL>
```

Figure 1: Example of the standard output

After a starting message the program informs the user about the input data. In this example it has read spec-

tral matrices of three magnetic and two electric components, the directions of electric antennae, power-spectral densities, and auxiliary data named MODE, XGSE, YGSE, ZGSE, DC_BX, DC_BY, and DC_BZ. Then PRASSADCO lists output data types and processing methods which are available with given data (see Section 4). Messages are printed during the data processing and finally the program prints a closing message. The corresponding graphic output is shown in Figure 9 (Appendix A.2).

4. Data types and processing methods

The example in Figure 1 demonstrates that each data type or processing method is characterized by a short name. In the present section the meaning of these names is briefly described.

Several methods work with a subset of available data and the user must specify the signals which enter into the processing. In the following list we use three symbols:

- *m* or *n* defines a single magnetic component in the "basic" frame. It stands for "1" (x-component), "2" (y-component) or "3" (z-component).
- *e* or *f* defines a single electric antenna. It stands for a number less or equal to the total number of antennae, beginning by 1. For STAFF-SA this means that *n* is either "1" (O1 component in the DS coordinate system – see Section 6.1) or "2" (O2 component).
- *l* defines a set (list) of electric antennae. It stands for a sequence of one or more numbers separated by "&"s, each of these numbers being less or equal to the total number of antennae. If the sequence is empty, the whole set of electric antennae is considered. For STAFF-SA this means that *l* stands for " ", "1&2" (both components), "1" (O1 component), or "2" (O2 component).

PRASSADCO implements eight main categories of output data types and processing methods:

4.1. Power spectral densities

The difference between power spectral densities and spectral matrices is discussed in Section 2.3.

PSD_B*m* : Power spectral densities of each magnetic signal separately

PSD_E*e* : Power spectral densities of each electric signal separately

PSD_BSUM : Sum of the three magnetic power spectral densities.

PSD_ESUM*l* : Sum of power spectral densities of selected electric antennae.

4.2. Auto-power spectra from the spectral matrices

B*m* : Auto-power spectra of each magnetic signal separately (magnetic component in the "basic" frame)

BSUM : Sum of the three magnetic auto-power spectra.

BSUMPERP : Sum of the two magnetic auto-power spectra corresponding to components along the x and y axes of the "basic" frame.

E*e* : Auto-power spectra of each electric signal separately.

ESUM*I*: Sum of auto-power spectra of selected electric antennae.

EXF,EYF, EZF, ESUMPERPF: Determination of the electric filed components in the "basic" frame. See section 4.6 below.

4.3. Analysis of the spectral matrix of three magnetic components

4.3.1. Determination of the wave vector direction in a single hemisphere

With the magnetic spectral matrix we cannot distinguish the two antiparallel directions. The wave vector direction is thus determined in a single hemisphere. The results are represented by a polar angle θ (0°-90°) and an azimuthal angle ϕ (0°-360°). The angle θ defines the deviation from the z-axis of the "basic"

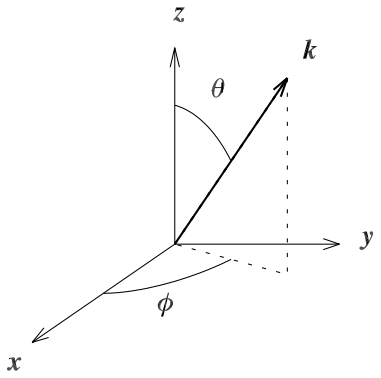

Figure 2: Definition of angles θ and ϕ in the "basic" coordinate system

coordinate system, whereas the angle ϕ defines the azimuth measured from the x-axis (see Figure 2). With the magnetic field data, the wave vector direction cannot be determined if the polarization is linear.

THM, PHM: Method of *Means* [1972] (a direct procedure using imaginary parts of three cross-spectra). THM gives θ, PHM gives ϕ.

THP, PHP: Method of *McPherron et al.* [1972] (eigenanalysis of the real part of the spectral matrix). THP gives θ, PHP gives ϕ.

THS, PHS: Method of *Samson and Olson* [1980] (a direct procedure using three cross-spectra). THS gives θ, PHS gives ϕ.

THSA, PHSA: Method of *Samson* [1973] (eigenanalysis of the compex the spectral matrix). THSA gives θ, PHSA gives ϕ.

THSVD, PHSVD: Singular Value Decomposition (SVD) of the spectral matrix based on equation $\vec{k} \cdot \vec{B} = 0$, where $\vec{k}$ is the wave vector and $\vec{B}$ is the wave magnetic field. This method solves a homogeneous set of six equations which take into account all information contained in the spectral matrix [*Santolík et al.*, 2003, equation 10]. It allows us to simultaneously determine the wave-vector direction (THSVD gives θ, PHSVD gives ϕ), the direction of axes of the polarization ellipse, its eccentricity, and the degree of polarization (see below).

THSVDANTI, PHSVDANTI : The same SVD method as for THSVD and PHSVD (see above) but the results are now transformed to the opposite hemisphere ($\theta \geq 90^o$): $\theta \longleftarrow 180^o - \theta$, $\phi \longleftarrow \phi + 180^o$.

4.3.2. Determination of the ellipticity and of the sense of polarization

The absolute value of the ellipticity describes the ratio of the the axes of the polarization ellipse and the sign defines the polarization sense. For the left-hand circularly polarized field the ellipticity is -1, a value of $+1$ corresponds to the right-hand circular polarization. Linearly polarized field has a zero ellipticity. Several methods are implemented for this composed quantity, and one method estimates the sense of polarization.

ELL : Ellipticity of *Samson and Olson* [1980]

ELLSA : Ellipticity of *Samson* [1973]

ELLSVD : Ellipticity from the SVD method [*Santolík et al.*, 2003, equation 13], values from -1 to 1; sign is added to reflect the polarization sense from the imaginary part of the cross-spectrum of the x and y components of the magnetic field.

ELLABSSVD : Absolute value of ELLSVD, L_p from [*Santolík et al.*, 2003, equation 13], values from 0 to 1.

SENSE : Sense of polarization with a level of confidence. Values below -1 mean left-hand polarized field, values above $+1$ correspond to the right-handed polarization. The absolute value gives the level of confidence, and values between -1 and $+1$ indicate a low confidence level (see equation (4) of *Santolík et al.* [2001a]).

E_ELLF, E_SENSEF : Ellipticity and sense of polarization of the electric field, see section 4.6 below.

4.3.3. Determination of coherence, degree of polarization and planarity of polarization

COHB*m*&*n* : Coherence between two magnetic signals $|S_{mn}|/\sqrt{S_{nn}\,S_{mm}}$, where S_{nn} and S_{mm} are the auto-power spectra, and S_{mn} is their cross-power spectrum; $1 \leq m,\ n \leq 3$.

COHE*e*&*f* : Coherence between two electric signals, see section 4.6 below.

COHBE*m*&*e* : Coherence between a magnetic signal and an electric signal, see section 4.6 below.

POLP : Method of *McPherron et al.* [1972]

POLS : Simplified method of *Samson and Olson* [1980],

$$P_{\mathrm{POLS}} = \sqrt{\frac{3}{2}\,\frac{\mathrm{trace}(\mathsf{S}^2)}{\mathrm{trace}^2(\mathsf{S})} - \frac{1}{2}}\ ,$$

where S is the spectral matrix 3×3 of magnetic components.

POLSA : Eigenanalysis method of *Samson* [1973] decribed by equation 32 in [*Samson*, 1973] or equation 18 of *Samson and Olson* [1980],

$$P_{\mathrm{POLSA}} = \sqrt{\frac{(\lambda_0-\lambda_1)^2+(\lambda_0-\lambda_2)^2+(\lambda_1-\lambda_2)^2}{2\,(\lambda_0^2+\lambda_1^2+\lambda_2^2)}}\ ,$$

where λ_0, λ_1, and λ_2 are the real eigenvalues of the Hermitian spectral matrix 3×3 of magnetic components.

PLANSVD : SVD method for planarity F of polarization defined as

$$F_{\mathrm{POLSVD}} = 1 - \sqrt{\frac{w_{\min}}{w_{\max}}},$$

where $w_{\min}$ and $w_{\max}$ are the minimum and maximum singular values, see equation 12 of *Santolík et al.* [2003].

POLSVD : Two-dimensional degree of polarization in the polarization plane,

$$C_{\mathrm{POLSVD}} = \sqrt{2\,\frac{\mathrm{trace}(\mathsf{R}^2)}{\mathrm{trace}^2(\mathsf{R})} - 1}\ ,$$

R being the spectral matrix 2×2 of magnetic components in the polarization plane, see [*Santolík and Gurnett*, 2002] or equation (A6) in the appendix of [*Santolík et al.*, 2002]. The polarization plane is obtained by the SVD method [*Santolík et al.*, 2003].

APLANSVD : SVD method for $1 - w_{\min}/w_{\mathrm{mid}}$, where $w_{\min}$ and w_{mid} are the minimum and middle singular values, see *Santolík et al.* [2003].

COHESVD : Coherence in the polarization plane $|R_{12}|/\sqrt{R_{11}\,R_{22}}$, where R_{11} and R_{22} are the auto-power spectra in the polarization plane, and R_{12} is their cross-power spectrum. The polarization plane is obtained by the SVD method [*Santolík et al.*, 2003].

EIGEN : Ratio of the largest eigenvalue of the Hermitian spectral matrix to the sum of the three eigenvalues.

EIGEN_SEC : Ratio of the second largest eigenvalue of the spectral matrix to the largest one.

EIGEN_THIRD : Ratio of the smallest eigenvalue of the spectral matrix to the largest one.

E_POLSVD, E_PLANSVD, E_EIGEN : Polarization and planarity of the electric field, see section 4.6 below.

4.3.4. Determination of the directions of the axes of the polarization ellipse

THPOLSVD, PHPOLSVD : SVD method *Santolík et al.* [2003] for determination of the direction of the major polarization axis. THPOLSVD gives θ between 0^o and 90^o, and PHPOLSVD gives an azimuthal angle ϕ between -180^o and 180^o. This direction lies in the plane perpendicular to the wave vector direction and is well defined only if the polarization is not circular. Note that for linearly polarized waves the method determines the direction in which the magnetic field fluctuates.

PTHPOLSVD, PPHPOLSVD : SVD method *Santolík et al.* [2003] for determination of the direction of the major polarization axis, with a modified definition of the resulting hemisphere (definition intervals of angles θ and ϕ). `PTHPOLSVD` gives θ between 0^o and 180^o, and `PPHPOLSVD` gives an azimuthal angle ϕ between -90^o and 90^o.

E_THPOLSVDF, E_PHPOLSVDF, E_PTHPOLSVDF, E_PPHPOLSVDF : similar SVD methods using the electric field data. See section 4.6 below.

PTHMINSVD, PPHMINSVD : SVD method *Santolík et al.* [2003] for determination of the direction of the minor polarization axis, with a modified definition of the resulting hemisphere (definition intervals of angles θ and ϕ). `PTHMINSVD` gives θ between 0^o and 180^o, and `PPHMINSVD` gives an azimuthal angle ϕ between -90^o and 90^o.

THPOLSA, PHPOLSA, THMINSA, PHMINSA : Eigenanalysis method of *Samson* [1973] for determination of the direction of the major (..POL..) and minor (..MIN..) polarization axes.

4.4. Analysis of the spectral matrix of three magnetic and one electric component

Even if more than one electric antenna is available, it is useful to check the results with each electric signal separately. It is supposed that the magnetic signals are orthogonal in the "basic" frame and the direction of the electric antenna is known in this frame.

EBPHASE*n* : Determination of the phase shift between the electric signal and a magnetic component B_P. This component is constructed in order to be perpendicular to both the electric antenna and the z-axis of the "basic" coordinate system. Detailed description of this procedure is given by *Santolík and Parrot* [1999]. A phase shift around $\pm 180^o$ corresponds to a positive z-component of the Poynting vector. A value near 0^o corresponds to a negative z-component.

PSIGN*n* : Estimation of the parallel component of the Poynting vector normalized by its standard deviation. This estimation is made using real parts of the cross-spectra between the electric signal and two perpendicular magnetic components [*Santolík and Parrot*, 1998, 1999]. Positive values correspond to a positive z-component of the Poynting vector.

4.5. Analysis of the spectral matrix of three magnetic and two electric components

It is supposed that the magnetic signals are in the "basic" frame and the directions of the two electric antennae (not necessarily perpendicular to each other) are known in this frame.

PSIGN*l* : Estimation of the parallel component of the Poynting vector normalized by its standard deviation. This procedure is an extension of the preceding method for two electric antennae [*Santolík et al.*, 2001a].

REFR*l*, ISHIFT*l* : Estimation of the refractive index and the impedance of the electric antennae using equation $n = c\vec{B}/(\vec{\kappa} \times \vec{E})$, where $\vec{\kappa} = \vec{k}/k$ and c is the speed of light. The method is based on the projection of the wave magnetic field to the direction perpendicular to the plane of electric antennae

[*Santolík et al.*, 2001a]. The wavevector direction $\vec{\kappa}$ is calculated by the method of *Means* [1972]. The refractive index cannot be separated from the absolute value of the transfer function Z of the antenna-plasma interface, and the procedure gives the ratio $n/|Z|$ of these two quantities (REFR*l*). With theoretical values of the refractive index, the transfer function (and thus the impedance of the electric antennae) can be estimated. The procedure also determines the phase shift due to the transfer function (ISHIFT*l*) varying between -180^o et $+180^o$. As a secondary effect, this value reflects the sign of the z-component of $\vec{\kappa}$. This is because the method of *Means* [1972] works only in a single hemisphere. Values below -90° or above +90° are equivalent to a negative κ_z with a phase shift reduced by 180°.

4.6. Analysis of the spectral matrix of all field components

The spectral matrix 6×6 of all field components can be obtained from the spectral matrix of three magnetic and two electric components using equation $\vec{E} \cdot \vec{B} = 0$. This equation is a consequence of the Faraday's law. It is used to calculate the third component of the electric field vector $\vec{E}$ [*Santolík et al.*, 2001a]. It is not necessary that the two electric antennae are orthogonal but their direction must be known in the "basic" frame.

The same processing methods can be used when the third electric component is directly measured. In that case it is not necessary to previously transform the original electric field signals into the "basic" frame but the three antennae must be orthogonal (this restriction is not fundamental and can be removed in future versions of PRASSADCO if needed). When a measured third electric component is supposed to be used, the short names given below must be modified by deleting the letter "F" (the last letter of each name).

4.6.1. Determination of the electric field components in the "basic" frame.

EXF, EYF, EZF : Components of the electric field in the "basic" frame of reference.

ESUMPERPF : Sum of the two electric auto-power spectra corresponding to components along the x and y axes of the "basic" frame.

4.6.2. Determination of the polarization properties of the electric field fluctuations.

COHE*e&f* : Coherence between two electric signals $|S_{ef}|/\sqrt{S_{ee}\,S_{ff}}$, where S_{ee} and S_{ff} are the auto-power spectra, and S_{ef} is their cross-power spectrum; $1 \leq e, f \leq N_e$, where N_e is the total number of electric antennas (2 for STAFF-SA; here the shorter version COHE can be used instead of COHE1&2 for the coherence between the signals from the two antennas).

COHBE*m&e* : Coherence between a magnetic signal and an electric signal $|S_{me}|/\sqrt{S_{mm}\,S_{ee}}$, where S_{mm} and S_{ee} are the auto-power spectra, and S_{me} is their cross-power spectrum; $1 \leq m \leq 3$, $1 \leq e \leq N_e$, where N_e is the total number of electric antennas (2 for STAFF-SA).

E_EIGEN, E_PLANSVD : The same as EIGEN and PLANSVD methods but for the electric field. All three components of the electric field must be measured to obtain these parameters (the "F" forms do not exist since their values would always be equal to one).

E_POLSVD : Two-dimensional polarization degree of the electric field. If all three components of the electric field are be measured, the method is the same as POLSVD method) but for the electric field. If only two electric components are measured, the method gives the two-dimensional polarization degree of the electric field in the plane of antennas. The "F" form does not exist.

E_ELLF, E_ELLSVDF, E_SENSEF : Ellipticity of the electric field polarization and sense of polarization. The same methods as the above described ELL, ELLSVD, and SENSE but for the electric field.

PHAS*e&f* : Phase shift between the signals of two electric antennas *e* and *f*. For STAFF-SA where only two antennas are used a shorter version PHAS without specifying antennas is available. Can be used as a robust method to calculate the ellipticity of polarization in the plane of electric antennas.

4.6.3. Determination of the directions of the axes of the polarization ellipse

AZIMUTH*e&f* : Azimuth of the main polarization axis calculated in the plane of two electric antennas *e* and *f*. For STAFF-SA where only two antennas are used a shorter version AZIMUTH without specifying antennas is available.

E_THSVDF, E_PHSVDF : Angles defining the electric field minimum variance direction in the "basic" frame of reference. SVD method is used [*Santolík et al.*, 2003] with the electric field data.

E_THPOLSVDF, E_PHPOLSVDF, E_PTHPOLSVDF, E_PPHPOLSVDF : SVD methods for direction of the major polarization axis. The same as THPOLSVDF, PHPOLSVDF, PTHPOLSVDF, and PPHPOLSVDF methods but for the electric field.

4.6.4. Determination of the Poynting vector

PSIGNF*l* : Parallel component of the Poynting vector normalized by its standard deviation. It is an extension of similar methods for one and two electric components [*Santolík et al.*, 2001a].

PSIGNXF*l*, PSIGNYF*l* : The perpendicular components of the Poynting vector normalized by their standard deviations [*Santolík and Gurnett*, 2002].

POYF*l*, THPOYF*l*, PHPOYF*l* : Direct determination of the Poynting vector as $\vec{E} \times \vec{B}/\mu_0$, where μ_0 is the vacuum permeability. The results are defined by the polar angle θ (THPOYF*l*) between 0^o and 180^o, azimuthal angle ϕ (PHPOYF*l*) between 0^o and 360^o, and by the spectral density of the Poynting flux in nW m^{-2} Hz^{-1} (POYF*l*). Values of $\theta < 90^o$ correspond to a parallel propagation with respect to the ambient magnetic field. Values $\theta > 90^o$ correspond to an antiparallel propagation.

4.6.5. Determination of the wave vector and electromagnetic planarity

THSVDEF*l*, PHSVDEF*l*, REFRSVDEF*l* : Direct procedure. The Faraday's law allows us to directly determine the wave vector from equation $\vec{k} \times \vec{E} = -\omega \vec{B}$, where ω is the wave frequency. With a spectral matrix 6×6 this equation results in an over-determined set of 36 equations for 3 components of the wave vector [*Santolík et al.*, 2003]. The SVD solution of this system is equivalent to a least squares optimization. The results are from the equation 22 of *Santolík et al.* [2003]: the

polar angle θ (THSVDEF*l*) between 0^o and 180^o, azimuthal angle ϕ (PHSVDEF*l*) between 0^o and 360^o, and the ratio of the refractive index to the absolute value of the antenna transfer function (REFRSVDEF*l*). This method assumes a zero phase shift due to the transfer function of the electric antennae.

PLANSVDEF : Electromagnetic planarity for a spectral matrix 6×6; F_E from equation 24 of *Santolík et al.* [2003]. NOTE: using the 'F' form of this method has no practical sense since it is always close to 1 (the third electric component is calculated using the Faraday's law for a plane wave). Only methods PLANSVDE and PLANSVDF (see below) are good to use practically, depending on the number of the electric components measured (this number is 2 for STAFF-SA, and therefore using PLANSVDF only makes sense).

PLANSVDF : Electromagnetic planarity for a spectral matrix 5×5; F_V from equation 37 of *Santolík et al.* [2003]. NOTE: removing 'F' from the name of this method leads to a completely different SVD-based method for a matrix 3×3 of the magnetic components (see section 4.3.3).

THSVDTF*l*, PHSVDTF*l*, REFRSVDTF*l* : Transformation to a homogeneous set of equations. If we need to take into account the imaginary part of the antennae transfer function, we must transform the above mentioned system of 36 equations to a homogeneous set [*Santolík et al.*, 2003]. After this, the SVD method is used to resolve this set, as described in equations 27 and 28 of [*Santolík et al.*, 2003]. The method calculates similar parameters as the direct procedure; the polar angle θ (THSVDTF*l*) between 0^o and 180^o, azimuthal angle ϕ (PHSVDTF*l*) between 0^o and 360^o, and the ratio of the refractive index to the absolute value of the antenna transfer function (REFRSVDTF*l* - [*Santolík et al.*, 2003], equation 29).

ISHIFTSVDTF*l*, PLANSVDTF*l* : The same method additionally provides us with another measure of the electromagnetic planarity (PLANSVDTF*l* - F_Z from equation 31 in *Santolík et al.* [2003]), and with the phase shift due to the antenna transfer function (ISHIFTSVDTF*l* - [*Santolík et al.*, 2003], equation 30)) having values between -90^o et +90^o.

4.7. Directions of electric antennae in the "basic" frame

ANTDIRX*n*, ANTDIRY*n*, ANTDIRZ*n* : Each of the antennae directions is represented by three components (X, Y and Z) of a unit vector.

4.8. Auxiliary data

The short names of auxiliary data are defined depending on the contents of the `*_aux.dat` file, see Figure 1 for an example.

5. Output

Output of PRASSADCO has different forms following the specifications given in the control file. The results of the analysis can be drawn in a figure or they can be written in a numerical form to an ASCII text file of an IDL binary save file. The file can either contain an exact numerical version of the figure or it can store an averaged spectral matrix prepared for further processing (e.g., by the Wave Distribution Function methods). A figure can be plotted to a screen preview, to a POSTSCRIPT file, or to a raster file of different formats (PNG, BMP, JPEG, TIFF, PPM, SRF, DICOM). These possibilities allow to process the data for preview and data selection purposes, for posting of a (PNG) figure on a www page, for publication-quality printout of the (POSTSCRIPT) figure, or for its possible transformation to a PDF file (see Section 7.2.2).

5.1. Time and frequency interval

The data are processed in a time and frequency intervals which are specified in the control file. The program can alternatively find the time and frequency minima or maxima by an automatic inspection of all available data. It is also possible to process a single data item at a given time and/or frequency (see Sections 7.2.4 and 7.2.5). If an averaged spectral matrix is stored to a text file, the average is made over both time interval and frequency interval. Otherwise, the results of the analysis can be presented in three modes: as a spectrogram, as a time series or as a frequency spectrum. The spectrogram results in non-averaged color-coded 3-D plots in the time-frequency plane. The time series consists of data averaged in the given frequency interval, and averages over the time interval are plotted in the frequency spectra (see Section 7.2.3). The standard deviations of the data are calculated during this averaging. They can be plotted together with the data (see item `STD` in Section 7.3.2).

5.2. Time discontinuities

The time dependent plots (spectrograms and time series) take into account discontinuities of the time coverage. A discontinuity occurs if the elementary time interval associated with a data item do not begin at the time expected from the previous data item. Deviations within 10% from this exact time are not considered as a discontinuity (this limit can be modified), se item `MAXREGERR` in Section 7.3.2. Each continuous time interval (data between two neighbor discontinuities) is plotted separately.

5.3. Time and frequency averaging of the spectral matrices

Besides the above described averaging of results, it is also possible to average the spectral matrices before their processing by different analysis methods. This is useful when the user wishes to reduce statistical errors on the input data. These errors are always induced by the spectral analysis during the previous processing. Additional averaging is always necessary if the original spectral matrices are not averaged at all (this is the case of band A data of STAFF-SA). PRASSADCO can do this additional averaging over several neighbor elementary frequency and/or time intervals. As a consequence of this procedure the frequency and time resolution is respectively decreased. The time discontinuities are taken into account when calculating the average matrices (items `TAVE` and `FAVE` in Section 7.3.2).

5.4. Panels

When the results are plotted on a figure they can be presented in one or several vertically superposed panels with a common horizontal axis (see Section 7.3). This common axis represents frequency for the frequency spectra and time for spectrogram or time series. A combination of of panels representing time series and other panels representing spectrograms is possible in the spectrogram mode (item AVERAGE in Section 7.3.2). The time axis of a spectrogram or a time series can be also annotated by one or more auxiliary data, for instance by the satellite position (see Section 7.2.6). These values are vertically stacked above each other below the tick marks corresponding to round time readings.

5.5. Data ranges

Each panel has its own vertical axis. For time series and for frequency spectra the maxima and minima of these axes are defined in the control file or they can be found automatically by the program (see Section 7.3.4). In the spectrogram mode, all the vertical axes represent the given frequency interval. In this mode a color scale is plotted on the right-hand side of each panel. The maxima and minima of these color scales axes are again defined in the control file or they can alternatively be found by the program. The annotation of the color scales or of the data axes of each panel can be fully defined by the user (see, e.g., item TICKNAMES in Section 7.3.2).

5.6. Thresholding

For each panel specific thresholds can be defined to exclude some data from the output. These thresholds can be based on results of any other methods included in PRASSADCO. For example, the user may want to plot results of ellipticity of *Samson and Olson* [1980] (method ELL) only for sufficiently intense signal, and let the results appear as missing data in time and frequency intervals where the sum of the three magnetic power-spectral densities (method BSUM) is lower than a predefined threshold. Foe more details about thresholding in PRASSADCO see items THRESHOLDS, THRESHOLD_ESUM, THRESHOLD_BSUM, and THRESHOLD_ELIP in Section 7.3.2.

5.7. Annotations

One or several lines of text may be plotted as titles on the top and on the bottom of the plot (see Section 7.2.7). Different commands can be used to annotate the figure with the actual time and frequency interval, with averaged values of auxiliary data, or with antennae directions (see Table 6). The user can create a legend to different line styles, plotting symbols, and line colors which are used in the panels (item LINEANNOTATION in Section 7.2.3). Selected parts of each panel may be marked by predefined lines, rectangles or arrows, and annotated by a text (items RECTANGLE, ARROW, and TEXTANNOT in Section 7.3.2). The user can also define comments to each panel which may be useful when view-graphs are created (item COMMENTS in Section 7.2.3, and item COMMENT in Section 7.3.2). Font style and character size may be defined for the majority of annotation texts on the plot (see item CHARSIZE in Section 7.2.2).

6. STAFF-SA data processing with PRASSADCO

6.1. STAFF-SA data in physical units: "N2" files

The above described PRASSADCO program is the final part of a chain of procedures designed for the STAFF-SA data processing. The way how to decode the telemetry information is described by *Harvey et al.* [1998] and by *Sitruk and Harvey* [1998]. In the end of this processing we have the data in physical units stored in an "N2" file. The data structures are variable to reflect the actual mode of operation of the instrument [*Sitruk and Harvey*, 1998]. The coordinate system used for the spectral matrices is the "Despun satellite coordinate system" (DS or SR2). The z-axis (O3) of this Cartesian system is parallel to the spin axis of the satellite, and the x-axis (O1) lies in the plane defined by the spin axis and the direction to the Sun [see *Sitruk and Harvey*, 1998, Section 3.6.1] or [*Harvey et al.*, 1998, Section 9.5].

6.2. Conversion of "N2" files to the PRASSADCO input format

Before using these data with PRASSADCO, they must be processed by the `read_N2SA` procedure. Its main task is to transform the STAFF-SA "N2" files to the binary input data of PRASSADCO. Similar procedures exist for the INTERBALL - MEMO data (`read_MEMO`), for the POLAR - HFWR data (`rpolar`), and for simulated data (`read_sim`).

The `read_N2SA` procedure reads one or several "N2" files. For each input record the mode of the instrument is decoded. With this information, the power-spectral densities and the spectral matrices are read and inserted to a data structure with a fixed record length. This data structure is the same whatever is the mode of instrument. The mode is stored as auxiliary data. A *prefix*`_log.txt` file is written during this processing. This ASCII file contains time of each input record, the decoded instrument mode, decoded information from the first DWP word, and a brief report on the consistence of input spectral matrices (see Figure 3). The file name is composed of two sequences: a variable part *prefix* and a fixed part `_log.txt`. The `read_N2SA` procedure constructs the variable part *prefix* from the pattern which defines the input "N2" files using the following rules:

- It omits the last "." (dot) and all what follows it.
- All "?" are replaced by "o".
- All "*" are replaced by "O".

For instance, the input "N2" files may be defined by a pattern
`$HOME/staff_sa/data/C?_991117_1_1a.n2sa`
In this case, *prefix* is expanded to
`$HOME/staff_sa/data/Co_991117_1_1a`

```
------------------------------------------------------------------------
---   read_N2SA - reading of Staff-SA (Cluster) N2 calibrated data   ---
---                       LOG file version (2001Jan30)               ---
------------------------------------------------------------------------
Created on Wed Jan 31 01:45:42 2001

Fields: (N2.rec no, time)  N2 file number, record number, time
        (C) satellite number
        (mode) STAFF-SA mode name          (ca) calibration on
        (wh) Whisper transmitter active        (sp) despin off
        (bu) burst mode on           (mo) STAFF-SA mode number
        (zd) Z boom pair in density mode   (yd) Y boom pair...
        (st) calibration step number 0..23  (st1) 1st DWP word
        (st2) 2nd status word (12345) errors in data, 5 types:
        1.PSD=0,      2.auto=0,       3.PSD<0,       4.auto<0,
        5.|cross_ij|^2>auto_i*auto_j;   found in "B":magnetic,
        "E":electric,     "M":mixed,    "*": several different




Number of STAFF-SA N2 files found: 4
STAFF-SA N2 FILE No 01: /home/os/staff_sa/data/C1_001212_1_2a.n2sa
STAFF-SA N2 FILE No 02: /home/os/staff_sa/data/C2_001212_1_2a.n2sa
STAFF-SA N2 FILE No 03: /home/os/staff_sa/data/C3_001212_1_2a.n2sa
STAFF-SA N2 FILE No 04: /home/os/staff_sa/data/C4_001212_1_2a.n2sa


N2.rec no C               rec time      mode ca wh sp bu mo zd yd st  st1  st2 12345
02.000001 2   2000-12-12 00:00:03.435    NM1  0  0  0  0  0  0  0  0    0    0
04.000001 4   2000-12-12 00:00:03.614    FM1  0  0  1  1  8  0  0  0 3800    0
04.000002 4   2000-12-12 00:00:04.614    FM1  0  0  1  1  8  0  0  0 3800    0
04.000003 4   2000-12-12 00:00:05.614    FM1  0  0  1  1  8  0  0  0 3800    0
04.000004 4   2000-12-12 00:00:06.614    FM1  0  0  1  1  8  0  0  0 3800    0
03.000001 3   2000-12-12 00:00:06.821    NM1  0  0  0  0  0  0  0  0    0    0
02.000002 2   2000-12-12 00:00:07.435    NM1  0  0  0  0  0  0  0  0    0    0
01.000001 1   2000-12-12 00:00:07.484    NM1  0  0  0  0  0  0  0  0    0    0
04.000005 4   2000-12-12 00:00:07.614    FM1  0  0  1  1  8  0  0  0 3800    0
```

Figure 3: Example of the *prefix*_`log.txt` file

6.3. Auxiliary information and coordinate systems

The `read_N2SA` procedure may optionally read a "Summary parameter" file containing auxiliary information on the position of Cluster satellites, their attitude and velocity [*Daly*, 1998]. All these data are added to the auxiliary information which may be used by PRASSADCO. Resulting names of auxiliary data types are the same as defined by [*Daly*, 1998]. Additionnaly, GSE, GSM, and magnetic dipole coordinates are calculated for each satellite.

The procedure can also optionally read a "Primary parameter" file containing the DC magnetic field data measured by the FGM device [*Daly*, 1998]. These data are also added to the auxiliary information which may be used by PRASSADCO.

With these data and with the attitude information the `read_N2SA` procedure transforms the magnetic

components and the directions of electric antennae to the $\vec{B}_0$ system of coordinates. In this Cartesian frame, z-axis is parallel to the actual DC magnetic field vector, and the x-axis lies in the plane defined by the DC magnetic field and the direction to the Sun. The attitude and the DC magnetic field data are not given with the same time base as the STAFF-SA data. The procedure thus calculates the middle points of the elementary time intervals associated to the STAFF-SA spectral matrices. The transformation is then done using linear interpolation of both the attitude and the DC magnetic field data to these middle time points.

If all the data which are necessary for this transformation are accessible, the "basic" frame for the spectral matrices is equivalent to the $\vec{B}_0$ system of coordinates. Without this transformation (by default) the "basic" frame is equivalent to the original DS (SR2) coordinate system.

The power spectral density data (`PSD_` - see Sections 2.3 and 4.1) must always stay in the original DS (SR2) coordinate system. As these data do not contain information about the cross-spectra the transformation to the $\vec{B}_0$ system is not possible.

6.4. Control file and output data

The input files of the `read_N2SA` procedure are defined by an ASCII control file, whose name is passed to the procedure as a parameter. An example of this file is given in Figure 10. If no parameter is specified a default name `read_N2SA.ini` is supposed. The first definition in this file is the name of the input "N2" file. This definition may contain wildcard characters to specify several "N2" files (see Section 6.2).

The second parameter defines the maximum size of one chunk of output data. The reason is that all these data must be placed in the memory during the processing. The size of input "N2"files can be more than 200 MByte per satellite. This would result in requirement of about the same amount of memory for all satellites during the processing, which could be a problem on an average computer. The `read_N2SA` procedure thus reads all the "N2" files, synchronizes the time of separate data records (data from differend satellites), and writes the data on the output in a sequence of chunks. Each of these chunks contains the data from all given "N2" files (all the satellites) during an interval of time. The length of this interval depends on the amount of data and on the specified memory size. 20 MByte corresponds approximately to 65 minutes of data in the normal mode from all 4 satellites (15 minutes of fast-mode data).

The user may optionally define a name of the "Summary parameter" file containing auxiliary information and names of four "Primary parameter" files of the FGM data (one file per satellite). The form of the control file is similar as the form of the PRASSADCO control file (see Section 7.2).

On the output, the `read_N2SA` procedure creates five types of files:

- *prefix*`_log.txt` ... text file containing detailed information on the input "N2" files (see 6.2).
- *prefix*`_err.txt` ... text file containing information on inconsistent data in the input "N2" files.
- *prefix_t1_t2*`_sm.dat` ... binary file containing the spectral matrices;
- *prefix_t1_t2*`_psd.dat` ... binary file containing the power-spectral densities;
- *prefix_t1_t2*`_aux.dat` ... binary file containing the auxiliary data.

The names of all output files are derived from the pattern defining input "N2" files (see Section 6.2), and as a consequence they are placed in the same directory. The sequence *t1_t2* in the names of output files is replaced by beginning and end of each chunk given in hours and minutes. This information is generated by the `read_N2SA` procedure during the processing. (Example of the resulting file name: `Co_001210_1_1a_0421_0526_sm.dat`)

If no specified "N2" file exists, only auxiliary data are saved with *prefix* derived from the first definition in the `read_N2SA` control file (see Figures 10 and 11). Otherwise, a list of all input "N2" files is stored to the third comment string in the header of the *prefix*`_sm.dat` file, recalled as item `%c3` in Table 6. The information about the actual "basic" coordinate system is stored to the second comment string in the header of the *prefix*`_sm.dat` file, recalled as item `%c2` in Table 6.

6.5. Flow chart of the STAFF-SA data processing with PRASSADCO

An automated chain of the data processing from the Cluster CD-ROM is integrated in the script `n2`. The script has two parameters. The first one is a name of the CD-ROM (example: 991117_1_1a). The second one is an optional parameter defining the source directory of the data. The default value defines the CD-ROM device (`/cdrom`). The script `n2` is based on a data processing script written by Luc Casagrande at CETP, which subsequently runs programs `levelone` decoding the telemetry information (TED), `decommute_SA` decoding the STAFF-SA data, and `n1toN2sa` converting the data to physical units.

The resulting "N2" files are then processed by the `read_N2SA` procedure called automatically from the `n2` script. The `n2` script uses a special `read_N2SA` control file, which is located in the `$HOME/staff_sa/prassadco` directory and its name is `_read_N2SA.ini`. It serves as a template for the control file `read_N2SA.ini` which is used by the `read_N2SA` procedure. In this file, the names of the input "N2", "Summary parameter" and "Primary parameter" files are automatically written by the `n2` script. The output files *prefix*`_log.txt`, *prefix*`_err.txt`, *prefix_t1_t2*`_sm.dat`, *prefix_t1_t2*`_psd.dat`, and *prefix_t1_t2*`_aux.dat` are by default placed in the directory `$HOME/staff_sa/data`.

Finally, the `n2` script calls the PRASSADCO program on all the time intervals contained in the original data. Three POSTSCRIPT plots are created from the data of all Cluster satellites. The first plot shows the power-spectral densities of electric and magnetic fields for all 4 satellites, mode of STAFF-SA operation, and the electron gyrofrequency (see Figure 5). The second and the third plots show several simple propagation parameters derived from the spectral matrices, and the DC magnetic field vector (Figure 7). All three types of plots are first generated from the data of each chunk separately, and then all the chunks are combined in global overview plots. As a result we obtain POSTSCRIPT files *prefix_t1_t2*`_pra00.ps`, *prefix_t1_t2*`_pra01.ps`, and *prefix_t1_t2*`_pra02.ps` for each chunk, and overview plots *prefix*`_O_pra00.ps`, *prefix*`_O_pra01.ps`, and *prefix*`_O_pra02.ps`.

To generate the plots, PRASSADCO is automatically called with control files created from templates destined for the `n2` script. To define the actual name of binary input files, the `n2` script always modifies the *prefix* string in these control files. The template control files are stored in the `$HOME/staff_sa/prassadco` directory and their names end by *_pra.ini*. The three default types of plots are defined by templates `_auto_pra.ini`, `_cross1_pra.ini`, and `_cross2_pra.ini`, but the user can modify the contents and/or number of these files (for instance, plot other parameters or change

output file format). An example is shown in Figures 4 and 6.

After running the `n2` script on a Cluster CD-ROM, the user may wish to prepare detailed plots using any of the PRASSADCO data processing methods and/or output formats. In this case she/he may manually modify a new copy of the PRASSADCO control file, as described in Section 7, and then run the PRASSADCO program as described in Section 3. Figures 8 and 9 show an example. Note that both IDL procedure `pra.pro` and script `pra` are by default located in the `$HOME/staff_sa/prassadco` directory.

The easiest sequence of operations to process the STAFF-SA data with PRASSADCO is therefore as follows:

1. If the "Summary parameter" and "Primary parameter" files are accessible, download them from a web site of the Cluster Science Data System (`http://sci2.estec.esa.nl/cluster/csds/world_sites.html`) and place them to the `$HOME/staff_sa/PPSP` directory.

2. Insert the CD-ROM and run the `n2` script with a command-line parameter defining the name of the CD-ROM. Example: `n2 991117_1_1a`. The second (optional) parameter of the `n2` script may define the path to the data. Example: `n2 991117_1_1a $HOME/cluster`. Take one or several cups of coffee.

3. Analyze the three overview figures *prefix*`_O_pra00.ps`, *prefix*`_O_pra01.ps`, and *prefix*`_O_pra02.ps` created by this script. (*prefix* stands for `$HOME/staff_sa/data/Co_`*cd-rom-name*, where *cd-rom-name* is the name of the CD-ROM defined in step 2).

4. Analyze figures from separate chunks *prefix*`_t1_t2_pra00.ps`, *prefix*`_t1_t2_pra01.ps`, and *prefix*`_t1_t2_pra02.ps`. These figures are also created by the script `n2` (step 2), and they generally have higher time resolution. Their names are similar as for the overview figures (step 3), but the sequence `_O_` is replaced by `_t1_t2_`. Here *t1* and *t2* are four-digit numbers used to define the beginning and the end of the time interval in hours and minutes. Example: `_1053_1158_`, `_1158_1319_`, etc.

5. Process the data in more detail with PRASSADCO, working on the *prefix*`_t1_t2_sm.dat`, *prefix*`_t1_t2_psd.dat`, and *prefix*`_t1_t2_aux.dat` files created in step 2: (a) Create a new copy of the PRASSADCO control file and modify it as described in Section 7. (b) Run the program as described in Section 3, it means by entering the command `pra,'`*control_file_name*`'` within an IDL session, or by running the script `pra` *control_file_name* in the `$HOME/staff_sa/prassadco` directory. Here, *control_file_name* stands for the name of the modified control file.

6. Repeat step 5 or process new CD-ROM data beginning from step 1 or do anything different.

7. Detailed description of the PRASSADCO control file

The control file consists of header, common definitions and an arbitrary number of panel definitions.

7.1. Header

The header consists of five lines of text:

```
;------------------------------------------------------------------------------
;--- PRASSADCO (PRopagation Analysis of Staff-SA Data with COherency tests) ---
;---                    Control file v 2000Jan19                            ---
;---                                                                        ---
;------------------------------------------------------------------------------
```

7.2. Common definitions

The header is followed by ten lines of common definitions. Each line contains a description text ended by ":". After this text a principal parameter must follow. The principal parameter may be defined by a numerical value or by a string value. Each line may additionally contain one or several optional parameters separated by commas ",". They may be placed on the line in an arbitrary order. The first optional parameter is separated from the principal parameter also by ",". An optional parameter may be a switch, a numerical value or a character string. A switch is represented just by the parameter name. A numerical value or a string value follows after the parameter name and a "=" sign. The parameter names are not case sensitive. If a ";" sign is present anywhere on the line, all the text following this sign is considered as a comment with no influence on PRASSADCO.

In the following text, the ten lines of common definitions are described is seven subsections. The subsections are always entitled by the corresponding description text. They always begin by an example of the corresponding line(s) in the control file.

7.2.1. File prefix

Example:

```
File prefix:          ../data/Co_19991117, REUSE ;
```

The principal parameter is a string defining the names of both input and output files. In the above example the input files are `../data/Co_19991117_sm.dat` (spectral matrices), `../data/Co_19991117_psd.dat` (power-spectral densities), and `../data/Co_19991117_aux.dat` (auxiliary data).

Note that it is not necessary that all these files exist. Availability of different data types and processing methods however depends on the input data actually found. As shown is Section 3 the program prints

out the messages informing the user about the available input data. All the analysis methods use the spectral matrices, and in case of problems with these input data, an error message is written: `Invalid spectral matrix data (input)`. If no information about the directions of electric antennae is present the program writes: `Supposing orthogonal electric components in the B0 system`, and does so during the data processing.

The string defining the names of input files may contain special characters "?" and "*". In that case all files expanded from the given string are sequentially processed and the results are combined into one single output file. This option can be for instance used when several chunks of input data have to be processed to a single figure. Note, however, that all automatic settings of maxima end minima are done only for the first input file found. It is thus desirable to avoid using "AUTO" option (see below) in such a case. The name of the output file is expanded from the input string using the following rules:

- All "?" are replaced by "o".
- All "*" are replaced by "O".

The line has one optional parameter

- `REUSE` (switch)

  If this switch is present, and if the data with the same prefix have been already read, they are not read again from the input files. Instead, they are reused from the memory. This option saves the time of processing when the user works several times with the same data. Note that the input data may be reused only within a single IDL session. They are always read from the input files when a new IDL session is started to run PRASSADCO. For instance, this switch has no effect when the script `pra` is run. Note also that information about available data types is written to the standard output only after reading the input data. It is not written when the data are reused.

7.2.2. Output type

Example:

```
Output type:          PS, FORCEDHEIGHT=PAGE, CHARSIZE=6 ;
```

The principal parameter is a string defining the PRASSADCO output. The user can choose one of the possibilities given in Table 1. Note that the GIF raster format is no longer supported by IDL and therefore it has been also removed from PRASSADCO.

If the principal parameter is not contained in the above list, the default output type `TIFF` is selected.

If an output file is created, the file name is generated automatically using the following scheme:

1. Name is created as indicated in Table 1, with the following substitutions: *prefix* is substituted by the file prefix parameter (see Section 7.2.1), and *XX* is first tentatively substituted by 00.

SCREEN	to plot a figure to a screen preview
PS	to plot a figure to a POSTSCRIPT file *prefix*_pra*XX*.ps
PNG, BMP, JPEG, TIFF, ...	to plot a figure to a raster file *prefix*_pra*XX*.*type* of the specified format, where *type* is png, bmp, jpeg, tiff, ppm, srf, dicom
ASC	to redirect the output to an ASCII file *prefix*_pra*XX*.asc
SAV	to redirect the output to an IDL binary save file *prefix*_pra*XX*.sav for structure sav with tags corresponding to all the items in the figure
SM	to save an averaged spectral matrix to a file *prefix*_pra*XX*.sm

Table 1: Output types

2. If such file already exist, *XX* is substituted by 01, 02, ... until a nonexisting file is found.
3. If all files with *XX* between 00 and 99 already exist, the file with *XX* = 99 is rewritten.

In the above example, a file name ../data/Co_19991117_pra00.ps is tried first. If this file already exists a file ../data/Co_19991117_pra01.ps is tried and so on. If the file cannot be opened for writing, a default file is created in the current directory.

The line has six optional parameters

- B&W (switch)

  If this switch is present, black and white plot is done. If the switch is absent the plot is in colors. Note that on the black and white spectrogram plots (see Section 7.2.3), some output types will not be well represented (e.g., the azimuthal angle ϕ of the wave vector).

- LETTER (switch)

  If this switch is present, the plot is made in the US letter format instead of the default A4 format.

- LANDSCAPE (switch)

  If this switch is present, the landscape orientation of A4 or US letter paper is used unless forced plot dimensions are defined using the parameters WIDTH and FORCEDHEIGHT (see below). Portrait is the default orientation.

- CHARSIZE = *a numerical value*

  Basic character size for the plot annotations. It controls all the character sizes in the plot. It directly defines the character size for annotation of axes. The sizes of tick lines and comments are related to this parameter via the TICKS_REL_SIZE and COMMENTS_REL_SIZE optional parameters (Section 7.2.3). Gaps between the panels are set to a half of CHARSIZE. The relative size of the plot titles can be redefined by the REL_SIZE optional parameter (Section 7.2.7).

  The value should be given in typographic points. It will apply on a POSTSCRIPT plot of default width, see the WIDTH parameter below. For POSTSCRIPT plots with other than default width the

character size will re-scale using the ratio of the widths. For the raster file or screen output the font size is adjusted to have the same relation to the figure width as on the POSTSCRIPT figure. The overall layout of the figure therefore doesn't change whatever is the output device and the plot width. If this optional parameter is not defined, the default character size is 10 pt.

- `WIDTH =` *a numerical value*

  For POSTSCRIPT plots the value gives the figure width in centimeters. The default width is the width of the A4 page with 2 cm margins on both sides (17 cm). For the raster file or screen output the value gives the figure width in pixels and the default width is 460 points. If the parameter `FORCEDHEIGHT` (see below) is not set to a user-defined value, the `WIDTH` parameter re-scales all the dimensions in the plot to conserve the layout. In this case, its only effect should be the change of the plot size.

- `FORCEDHEIGHT =` *a numerical value* or `PAGE`

  For POSTSCRIPT plots the value gives the figure height in centimeters. If this optional parameter reads `FORCEDHEIGHT=PAGE` the height is calculated to have the same ratio to the width as on the A4 paper with 2 cm margins on all sides (for the default width this gives a height of 25.7 cm). The default is the sum of heights if the plot panels, horizontal axis annotations, titles, and gaps between the panels (see Section 7.3.3).

  For the raster file or screen output the value gives the figure height in pixels. If this optional parameter is not defined or if it reads `FORCEDHEIGHT=PAGE` the height is calculated to have the same ratio to the width (the same layout) as on a POSTSCRIPT plot.

7.2.3. Plot type

Example:

```
Plot type:          spectrogram, comments, SOURCE=-1
```

The principal parameter is a string defining the type of plot output. Three possible plot types are briefly described in Table 2.

`SPECTROGRAM`	The results are plotted in color-coded time-frequency spectrograms in a predefined time interval and a predefined frequency interval. The color scale is plotted on the right-hand side of each panel.
`SERIES`	The results are plotted as time series averaged in a given frequency interval.
`SPECTRUM`	The results are plotted as frequency spectra averaged in a given time interval.

Table 2: Plot types

The line has eight optional parameters

- `SOURCE =` *a numerical value*

  Identification of the data source. For STAFF-SA this number corresponds to the number of the CLUSTER satellite. If a value of -1 is set, all the data found in the input file are processed. If this optional parameter is not set, data sources indicated for each panel separately are taken into account (see Section 7.3.1) .

- `COMMENTS =` *a numerical value* or (switch)

  Space for left-hand side comments. The value should be expressed as a number of average character widths. If the option is used as switch, the default value of 20 approximately corresponds to 20 characters on a single line of comments. If the option is absent, no space is left and no left-hand side comments are placed on the output plot.

- `LINEANNOTATION =` *a string*

  This option allows to draw annotations to the line styles and colors which are used for different data. Each annotation consists of a short line and an explanatory text. Arbitrary number of annotations can be placed everywhere on the plot. In the definition string, their particular definitions are separated by "&&". Each particular definition has seven fields separated by "&"s:

  posx & *posy* & *color* & *text* & *thickness* & *linestyle* & *symbol*

  posx, *posy*: First two fields define position of the lower left edge of the annotation. Both coordinates are real numbers between 0 and 1. *posx* = 0 means the left edge of the plot, *posx* = 1 means the right edge of the plot, *posy* = 0 means the lower edge of the plot, *posy* = 1 means the top edge of the plot.

  color: The third field defines color of the annotation. It is interpreted in the same manner as the `COLOR` optional parameter of `Data type` described in Section 7.3.2). Black is the default color. The leading and trailing spaces in this field are not taken into account.

  text: The fourth field defines the annotation text. All spaces between the two "&" signs are reproduced on the plot. The font size is the same as for the annotation of plot axes (see the `CHARSIZE` optional parameter of the `Output type` line, Section 7.2.2). IDL text positioning and font selection commands may be used inside the text (see Table 5).

  thickness: The fifth field defines the line thickness in 0.1 mm (on the POSTSCRIPT figure). The line thickness is the same as defined the `THICKNESS` optional parameter of `Data type` in Section 7.3.2).

  linestyle: The sixth field defines the line style as described by the `LINESTYLE` optional parameter of `Data type` (Section 7.3.2).

  symbol: The seventh field defines the plotting symbol as described by the `SYMBOL` optional parameter of `Data type` (Section 7.3.2).

  If a definition string for a particular annotation contains less than 4 fields, the first existing field is interpreted as *posx*, the second one (if exists) as *posy*, the third one (if exists) as *color*, and so on. Default values are used for remaining undefined fields.

  If the number of fields inside a definition string for a particular annotation is greater than 7, only the first 7 fields are taken into account. In this case the following warning is printed. `Warning: Some fields in LINEANNOTATION item no.` *X* `have been omitted:` *text*, where *X* stands for the annotation item number as deduced from the sequence of subsequent "&&" strings, and *text* stands for the text which is interpreted as the concerned annotation item.

For instance, if the option reads `LINEANNOTATION= 0.1&0.5&BLUE& Nice data& &1 &&0.1&0.52 RED & Ugly data&10`, PRASSADCO creates two annotations. Both of them are on the left-hand side of the plot approximately in the middle of its height. The bottom annotation contains a thin blue dotted line and a blue text " Nice data". The second annotation contains a thick red line followed by a red text " Ugly data". The user is expected to enter much more reasonable optional parameters than the above example.

- `TIMEAXIS` (switch)

  If this switch is present the horizontal axis of spectrogram or series is directly annotated by MJD time data (in days) without decoding the modified Julian date. By default, the annotation is made as defined in Section 7.2.6.

- `TIMETITLE =` *a string*

  If the switch `TIMEAXIS` is set, this optional parameter defines the title of the time axis. This title is written on the bottom of the time axis annotation. By the default, the titles are written on the left side of annotation as defined in Section 7.2.6.

- `LEFTSPACE =` *a numerical value*

  Space for the annotation of the left-hand vertical axis. The value should be expressed as a number of average character widths. The default is approximately 10 characters.

- `SCALESPACE =` *a numerical value*

  Space for color scales on the right-hand side of the plot (in the `SPECTROGRAM` mode only). The value should be expressed as a number of average character widths. The default is approximately 14 characters.

- `COMMENTS_REL_SIZE =` *a numerical value*

  Relative font size used to plot the left-hand side comments of each plot. It should be given as a real number. It defines the magnification factor relative to the font of axis annotation (see the `CHARSIZE` optional parameter of `Output type` in Section 7.2.2). The default value of 1.2 results in comments written by larger letters than the axis annotation. For instance, if the axes are annotated (as by default) with a 10pt font, the comments are written by a 12pt font.

- `TICKS_REL_SIZE =` *a numerical value*

  Relative length of tick lines used to annotate the plot axes. It should be given by a real number. It defines the magnification factor relative to the axis annotation font (see the `CHARSIZE` optional parameter of `Output type` in Section 7.2.2). The tick length is related to the approximate width (horizontal dimension) of an annotation character. The same length is used for both horizontal and vertical axes. The default value of 0.5 results in relatively short ticks (one half of the character width). For instance, if the axes are annotated with a 10pt font, the default tick lines are about 2 points (0.7mm) long.

7.2.4. Min time, Max time

Example:

```
Min time:            1999-11-17 13:00:00
Max time:            1999-11-17 13:00:00
```

These two lines of the control file specify the time interval for the data analysis. The minimum time and the maximum time are defined as principal parameters. Both are character strings with three syntactic possibilities defined in Table 3.

`AUTO`	the minimum or the maximum time is found by an automatic inspection of all available data.
`YYYY-MM-DD HH:MM:SS`	the time is defined by year (four digits), month (two digits), day of month (two digits), hour (two digits), minute (two digits), and second (two digits). A one-character separator is placed between the neighboring fields.
`YYYY-MM-DD HH:MM:SS.MSC`	the time is defined as before, but now with a millisecond resolution. A separator and three digits of millisecond are added in the end of the string.

Table 3: Definition of the time interval

Any non-numerical characters can be used as separators between the six or seven date and time fields. For instance `2000/02/21T08.59.59` is a valid input, `2000002/21T08.59.59` is not. Invalid input strings will produce error messages:

```
Error reading pra.ini on line 9 (Min time:)
Error reading pra.ini on line 10 (Max time:)
```

If the second or third syntactic possibility is used, the program always proceeds with all the data items whose elementary time intervals overlap with the specified time interval. In other words, if the specified time falls inside an elementary time interval or at any of its two boundaries, the corresponding data are taken into account. For instance, a single data item may be selected by defining the same value for both minimum and maximum time, as shown by the example in the beginning of this subsection. Note however that no data are selected when the specified time falls in a gap between two neighbor elementary intervals. In that case a default plot is produced.

The information about the data actually contained in the selected time interval can be written on the plot or to the output ASCII files (see Section 7.2.7).

7.2.5. Min frequency, Max frequency

Example:

```
Min frequency:       500.
Max frequency:       500.
```

These two lines define the frequency interval for the data analysis. The principal parameters are the minimum frequency and the maximum frequency. Both have two syntactic possibilities described in Table 4.

AUTO	the minimum or the maximum frequency is found by an automatic inspection of all available data.
a numerical value	a user supplied definition of the minimum or the maximum frequency.

Table 4: Definition of the frequency interval

Similarly as for the time interval, the program takes into account all the data items whose elementary frequency intervals overlap with the specified frequency interval. For instance, a single frequency interval can be selected by defining the same value for both frequency minimum and maximum. A default plot is produced if no elementary frequency intervals are found between the specified frequency minimum and maximum.

The information about the data actually contained in the selected frequency interval may be written on the plot or to the output ASCII files (see Section 7.2.7).

7.2.6. Orbit information

Example:

```
Orbit information:   UT XGSE YGSE ZGSE ;
```

This parameter defines a list of data which are used to annotate the horizontal axis of a spectrogram or a series plot. Each item of the list corresponds to one line of annotations. The number of lines is arbitrary. The axis may be annotated by any of the available auxiliary data and/or by the time. The list items corresponding to the auxiliary data are defined by their respective short names (see Section 4.8). If a list item reads "UT" the respective line of annotation will contain time information. Neighbor list items are separated by blanc spaces. The position of the tick marks is always controlled by the time, even if the "UT" item is not present in the list.

If the list is empty, only tick lines are plotted on the horizontal axis without any annotation label. This may be useful if the current plot is designed to be placed on the top of another figure which is already annotated in the same time interval. If the list contains a word which doesn't correspond to a name of any auxiliary data, and which is different from "UT", a message is printed:
`Invalid orbital information`.

7.2.7. Title (top), Title (bottom)

Example:

```
Title (top):   %c1 %t1 - %t2  (%f1 - %f2) Hz X%XGSE %YGSE %ZGSE
Title (bottom):   %lfAll data from %c3 %c2%lfPlot created %now by %ver.
```

The top (bottom) title is one or more lines of text which is written on the top (bottom) of the plot page. The principal parameters are strings of characters, which may contain any text including IDL font selection and text positioning commands. Table 5 briefly recalls some of these commands from *IDL reference guide* [1999].

!3	Select the Helvetica font for the POSTSCRIPT output device (the default).
!9	Select the Symbol font for the POSTSCRIPT output device. The Greek letters correspond approximately to somewhat similar Latin characters (a for α, q for θ, f for ϕ, and w for ω).
!4	Select the Helvetica Bold font for the POSTSCRIPT output device.
!7	Select the Times Roman font for the POSTSCRIPT output device.
!8	Select the Times Bold Italic font for the POSTSCRIPT output device.
!3	Select the the Simplex Roman font for the screen or GIF output devices (the default).
!7	Select the Greek font for the screen or GIF output devices. The Greek letters correspond approximately to somewhat similar Latin characters (a for α, h for θ, u for ϕ, and x for ω).
!6	Select the Complex Roman font for the screen or GIF output devices.
!8	Select the Complex Italic font for the screen or GIF output devices.
	.....
!U	Set the upper index mode.
!D	Set the lower index mode.
!N	Return to the normal mode.
	.....

Table 5: Some IDL font selection and text positioning commands

The title string may also include special sequences which allow the user to print different information about the data. Complete list of these sequences is given in Table 6.

Both lines of the control file may contain two optional parameters:

- `HORIZPOS =` *a numerical value*

  Horizontal position of the left edge of the title text on the plot. It should be given by a real number between 0 and 1. The default value of 0 means the left edge of the plot and gives a left-justified text.

%lf	The text following this special sequence is placed on a new line. If no text follows a blanc line is created. The title may contain any number of lines.
%t1	Replaced by a string which indicates the beginning of the elementary interval of the first data in the plot.
%t2	Replaced by a string which indicates the end of the elementary interval of the last data in the plot.
%tis	Replaced by the total time interval of all the data contained in the plot (in seconds).
%tim	Replaced by the total time interval of all the data contained in the plot (in minutes).
%tih	Replaced by the total time interval of all the data contained in the plot (in hours).
%f1	Replaced by the lowest frequency in the plot.
%f2	Replaced by the highest frequency in the plot.
%fi	Replaced by the total frequency interval of all the data contained in the plot.
%ver	Replaced by the PRASSADCO version.
%c1	Replaced by the first comment string found in the header of the input data.
%c2	Replaced by the second comment string found in the header of the input data.
%c3	Replaced by the third comment string found in the header of the input data.
%antdirx*n*	Replaced by an average x-component of the direction of the *n*th electric antenna. The average is made over the time interval of the plot.
%antdiry*n*	Replaced by an average y-component of the direction of the *n*th electric antenna.
%antdirz*n*	Replaced by an average z-component of the direction of the *n*th electric antenna.
%"*a short name of auxiliary data*"	Replaced by an average value of the respective auxiliary data. The average is made over the time interval of the plot.

Table 6: Special sequences for printing information about the data

The value of 0.5 would produce a title beginning in the middle of the horizontal dimension of the plot.

- `REL_SIZE =` *a numerical value*

  Relative font size used to plot the titles. It should be given by a real number. It defines the magnification factor relative to the font of axis annotation (see the `CHARSIZE` optional parameter of `Output type` in Section 7.2.2). The default values are 1.2 for the top title and 0.8 for the bottom title. For instance, if the axes are annotated with a 10pt font (the default), the top title is written by a 12pt font and the bottom title is written by a 8pt font.

7.3. Panel definitions

After the common definitions an arbitrary number of panels may be defined. Each panel definition consists of one separation line followed by five lines of panel-specific parameters. Each line has the same basic syntax as in the common definitions (a principal parameter and optional parameters - see Section 7.2).

In the following text, the five lines of panel-specific definitions are described is four subsections. The subsections are entitled by the corresponding description text, and they always begin by an example of the corresponding line(s) in the control file.

7.3.1. Data source

Example:

```
Data source:         -1
```

Number of a data source set for each panel separately. For STAFF-SA this number corresponds to the number of one of the CLUSTER satellites. If a value of -1 is set, all the data found in the input file are processed. This parameter is overridden with the optional parameter `SOURCE` of the plot type (Section 7.2.3).

7.3.2. Data type

Example:

```
Data type:         bsum
```

The principal parameter defines a data type or processing method which will be used in this panel. One of the short names, as listed in Section 4, should be used. If the data type is not found in this list a default output is plotted in the respective panel, and a message is printed to the standard output:
`Error:  Unknown data type`

The line may have a number of optional parameters.

- `OVERPLOT` (switch)

  If this option is set, the results are not plotted in a separate panel. Instead, the graphics is drawn over the information already contained in the preceding panel. This is particularly useful if several different data or processing results should be presented in the same spectrum or time-series panel. It is also useful if characteristic frequencies (from auxiliary data) have to be drawn over the spectrograms.

  The parameters `Panel Size`, `Min data`, and `Max data` (see below) are used as defined for that preceding panel, and these settings for the current panel have no effect. Any number of subsequent `OVERPLOT`ed panels may be created. If this option is used in the first panel just after the common definitions, it has no sense and the data are normally placed in a separate panel.

- `AVERAGE` (switch)

  If this option is present in the spectrogram mode, the data as plotted as a time series. The averaging of results is done over the whole frequency interval, as defined by the `Min frequency` and `Max frequency` parameters (Section 7.2.5). The option has no effect when either the time series mode or the spectrum mode is set.

- `TAVE =` *a numerical value*

  Number of neighbor elementary time intervals to average. The averaging is done at the level of input spectral matrices, before any processing. This procedure reduces the statistical errors on each component of the input matrices by a factor of $\sqrt{\texttt{TAVE}}$. It also reduces the time resolution of results by a factor of `TAVE`. The time discontinuities are taken into account in such a way, that the data are averaged only inside time intervals continuously covered by the data. The data separated by a time discontinuity may never be mixed together in a single average matrix. Several data items in the end of a continuous time interval may be excluded from the processing, as the procedure averages always exactly `TAVE` items. When the number of items in a continuous time interval is less than `TAVE` this time interval is excluded from the processing. The option has no effect when auxiliary data or antennae directions are plotted.

- `FAVE =` *a numerical value*

  Number of neighbor elementary frequency intervals to average. The averaging is done at the level of input spectral matrices, before any processing. This procedure reduces the statistical errors on each component of the input matrices by a factor of $\sqrt{\texttt{FAVE}}$. It also reduces the frequency resolution of results by a factor of `FAVE`. The option has no effect when auxiliary data or antennae directions are plotted.

- `TICKVALUES =` *a string*

  This optional parameter defines the positions of tick marks on the data axis. The data axis is the vertical axis of a panel in a spectrum or a time-series plot, and the color-scale axis corresponding to a panel in a spectrogram plot.

  The positions are given by a sequence of real values separated by "`&`"s. For instance, a sequence `TICKVALUES =0.5&0.7&1.` makes the plot with three annotated tick marks on the data axis. The sequence may contain between 2 and 30 fields.

  If the number of fields is less than 2 or more than 30, or if some fields contain non-numerical information an error message is printed: `Invalid TICKVALUES option`.

  By the default the tick positions are generated automatically.

- `TICKNAMES =` *a string*

  Tick mark annotations on the data axis (color scale for a spectrogram plot, vertical axis of the plot otherwise). The option is structured into several (up to 30) fields, separated by the "`&`" signs. First field corresponds to the lowest tick mark. IDL font selection and text positioning commands may be used inside each field (see Table 5). The option may be also used when the `TICKVALUES` option is not set and the tick values are chosen by the program. If some fields are null (sequences "`&&`" are encountered), automatically generated numerical annotations are used for the corresponding tick marks. If the number of tick marks is higher than the number of fields of this option, automatically generated numerical annotations are used for the remaining tick marks. If the number of fields is higher than 30 an error message is printed: `Invalid TICKNAMES option`.

- `MINORTICKS =` *a numerical value*

  Number of intervals between two neighbor tick marks which is used to generate minor ticks on the data axis. By the default, this value is automatically selected by the program.

- `TITLE =` *a string*

  Title of the data axis (color scale for a spectrogram plot, vertical axis of the plot otherwise). By the default, a title which corresponds to the selected data type is automatically generated by the program. This default title can be inserted to a user-defined title using the "`%def`" control sequence.

- `FRQTIT =` *a string*

  Title of the frequency axis (vertical axis of a spectrogram plot, horizontal axis of a spectrum, no effect on a time-series plot). By the default, a title is automatically generated by the program, depending on the header of the input file. This default title can be inserted to a user-defined title using the "`%def`" control sequence.

- `FRTICKVAL =` *a string*

  The same as `TICKVALUES =` (see above) but for the frequency axis.

- `FRMINOR =` *a numerical value*

  The same as `MINORTICKS =` (see above) but for the frequency axis.

- `NOSCALE` (switch)

  If this switch is present, the color bar on the right hand side of the spectrogram is not plotted (in the `SPECTROGRAM` mode only).

- `COMMENT =` *a string*

  Left-hand side comment of the panel. It may by divided into several lines of text using the "`%lf`" control sequence (see Section 7.2.7) By the default, a comment is automatically generated by the program, corresponding to the selected data type or processing method. This default comment can be inserted to a user-defined comment using the "`%def`" control sequence.

- `FUNCTION =` *a string*

  A user-defined function. This optional parameter has no effect if the `Data type` parameter is other than auxiliary data (see Section 4.8) or antennae directions (Section 4.7). The results obtained by evaluation of the function will be drawn instead of the selected data. The function must be written using the syntactic rules of the IDL language (e.g., "`*`" for the multiplication sign, "`SQRT(x)`" for

a square root $\sqrt{x}$, "`x ^ y`" for x^y, ...). Short names of auxiliary data and/or antennae directions may be used as variables of this function. For an example, see the last panel definition in Figure 8. If an error is encountered while evaluating the function, a message is written:
`Error executing user defined function`.

- `INTERPOINTS =` *a numerical value*

  Number of interpolation points. This optional parameter has no effect if the `Data type` parameter is other than auxiliary data (see Section 4.8) or antennae directions (Section 4.7). The results obtained by interpolation inside the plotting interval will be drawn. The interpolation is done using cubic splines.

- `AVEPOINTS =` *a numerical value*

  Number of subintervals for data averaging. This optional parameter has no effect if the `Data type` parameter is other than auxiliary data (see Section 4.8) or antennae directions (Section 4.7). The plotting time interval is divided into the specified number of equal subintervals, and the data contained is each subinterval are averaged. Each average is plotted with the time of the middle of the corresponding subinterval.

- `USE_INT` (switch)

  This option has no effect if fixed time and frequency intervals are defined (Sections 7.2.4 and 7.2.5). If one of the intervals is used with the `AUTO` option, all panels are normally searched for time or frequency minima and maxima. If option `USE_INT` is present, the time and frequency interval of data contained in this panel is not taken into account.

- `COLOR =` *a string*

  Color of the line and/or plotting symbols which are used to draw the data. This optional parameter has no effect in a spectrogram panel. The color has to be defined by one of the following strings:

  `WHITE BLACK GREY RED BLUE GREEN YELLOW CYAN VIOLET`

  The parameter is not case sensitive. The default color is black.

- `THICKNESS =` *a numerical value*

  An optional parameter defining the thickness of the line which connects points in the plot. It also specifies the thickness of the line used to plot the symbols at each point. The units are 0.1 mm on the POSTSCRIPT figure. For a screen output and for a GIF file the thickness is adjusted to be approximately in the same relation to the figure width as on the postscript figure. In any case there are some obvious limitations (e.g., the lowest possible line thickness) imposed by the output devices. The parameter has no effect in a spectrogram panel. The thinnest possible line is the default.

- `LINESTYLE =` *a numerical value*

  Style of the line connecting the data in a spectrum or a time-series plot. The parameter has no effect in a spectrogram panel. It is defined by numerical values defined in Table 7.

- `SYMBOL =` *a numerical value*

  Plotting symbol used to draw separate data points in a spectrum or a time-series plot. The parameter has no effect in a spectrogram panel. The correspondence between the values and plotting symbols is given in Table 8. Negative values `-1` through `-7` cause the symbols to be plotted with solid lines connecting the symbols.

0 or lower	solid line
1	dotted line
2	dashed line
3	dash-dot
4	dash-dot-dot
5 or greater	long dash

Table 7: Line styles

- RECTANGLE = *a string*

  This optional parameter serves to draw an arbitrary number of annotated rectangles over the data plot. It is useful, e.g., when some parts of a spectrogram should be highlighted and annotated by a text. It may also be used to draw horizontal or vertical lines at a given frequency, time, or data value in a spectrum or in a time-series plot. In the definition string, definitions of particular rectangles are separated by "&&". Each of these definitions has nine fields separated by "&"s:

  x1 & *y1* & *x2* & *y2* & *color* & *thickness* & *text* & *text position* & *fill spacing*

  x1, *y1*, *x2*, *y2*: Position of the edges of the rectangle in the data coordinates. In a spectrogram or a time-series plot, *x1* and *x2* may defined by any of the two forms of the time definition string (see Section 7.2.4). In a spectrum, *x1* and *x2* define frequency interval where the rectangle will be drawn. *y1* and *y2* define a frequency interval in a spectrogram, a data interval otherwise. If either *x1* and *x2* are the same or *y1* and *y2* are the same, a horizontal line or a vertical line is respectively drawn. If any of the four fields remains undefined (a blanc space is typed in its place), the respective coordinate is automatically placed on the edge of the panel. For instance, a parameter defined by "RECTANGLE = &0.& &0.&&1999-02-21 02:13:00& &1999-02-21 02:13:00" results in two lines; a horizontal one drawn at the zero level over all the panel width, and a vertical one beginning on the bottom and ending on the top of the panel and placed at the time as specified.

  color: Color of the rectangle and of the text annotation. The field is defined as described for the COLOR optional parameter in Section 7.3.2. Black is the default.

  thickness: Thickness of lines used to draw the rectangle. The field is defined as described for the THICKNESS optional parameter in Section 7.3.2. The thinnest possible line is the default.

  text: An annotation text to be written next the rectangle. It may contain IDL text positioning and font selection commands as recalled in Table 5.

-1 or 1	Plus sign (+)
-2 or 2	Asterisk (*)
-3 or 3	Period (.)
-4 or 4	Diamond
-5 or 5	Triangle
-6 or 6	Square
-7 or 7	X
10	Histogram mode

Table 8: Plotting symbols

text position: If this field is undefined or zero, the annotation text is written above the rectangle. With a value of 1 the text is written on the right-hand side of the rectangle.

fill spacing: Defines spacing in cm of oblique parallel lines which fill the interior of the rectangle. A value of 0 means solid fill by a given *color*. If this field is absent no filling is done.

If any of these fields are absent from the definition string they are automatically defined by their default values.

- `ARROW =` *a string*

  This optional parameter serves to draw an arbitrary number of annotated arrows over the data plot. It is useful, e.g., when some parts of a spectrogram should be highlighted and annotated by a text. In the definition string, definitions of particular arrows are separated by "&&". Each of these definitions has eight fields separated by "&"s:

  x1 & *y1* & *x2* & *y2* & *color* & *thickness* & *text* & *text position*

  x1, *y1*, *x2*, *y2*: Position of the ends of the arrow in the data coordinates (the arrowhead is at *x2*, *y2*). In a spectrogram or a time-series plot, *x1* and *x2* may defined by any of the two forms of the time definition string (see Section 7.2.4). In a spectrum, *x1* and *x2* define frequency interval where the arrow will be drawn. *y1* and *y2* define a frequency interval in a spectrogram, a data interval otherwise. If either *x1* and *x2* are the same or *y1* and *y2* are the same, a horizontal arrow or a vertical arrow is respectively drawn. If any of the four fields remains undefined (a blanc space is typed in its place), the respective coordinate is automatically placed on the edge of the panel. For instance, a parameter defined by "`ARROW = &0.& &0.&&1999-02-21 02:13:00& &1999-02-21 02:13:00`" results in two arrows; a horizontal one drawn at the zero level over all the panel width, and a vertical one beginning on the bottom and ending on the top of the panel and placed at the time as specified.

  color: Color of the arrow and of the text annotation. The field is defined as described for the `COLOR` optional parameter in Section 7.3.2. Black is the default.

  thickness: Thickness of lines used to draw the arrow. The field is defined as described for the `THICKNESS` optional parameter in Section 7.3.2. The thinnest possible line is the default.

  text: An annotation text to be written next the arrow. It may contain IDL text positioning and font selection commands as recalled in Table 5.

  text position: If this field is undefined or zero, the annotation text starts at the beginning of the arrow. With a value of 1 the text starts at the arrowhead.

  If any of these fields are absent from the definition string they are automatically defined by their default values.

- `TEXTANNOT =` *a string*

  This optional parameter serves to add an arbitrary number of text annotations to the data plot. In the definition string, definitions of particular text annotations are separated by "&&". Each of these definitions has four fields separated by "&"s:

  x & *y* & *color* & *text*

  x, *y*: Starting position of the text annotation in the data coordinates In a spectrogram or a time-series plot, *x* can defined by any of the two forms of the time definition string (see Section 7.2.4). In a spectrum, *x* defines frequency where the text should start. *y* defines a starting frequency in a

spectrogram, data otherwise. If any of the two fields remains undefined (a blanc space is typed in its place), the respective coordinate is automatically placed on the edge of the panel.

color: Color of the text annotation. The field is defined as described for the COLOR optional parameter in Section 7.3.2. Black is the default.

text: An annotation text. It may contain IDL text positioning and font selection commands as recalled in Table 5.

If any of these fields are absent from the definition string they are automatically defined by their default values.

- STD = *a string* or (switch)

  If this parameter is set, standard deviations are plotted together with the time-series or spectrum data. The standard deviations are calculated when the results are averaged in a given frequency or time interval. The parameter has no effect in a spectrogram panel. If it is used as a switch (without "=" and without the definition string) the standard deviations are represented by solid vertical lines of the same color as the data. If the definition string is used, it consists of five fields separated by "&"s.

  orientation & *thickness* & *color* & *linestyle* & *spacing*

  orientation: Angle (in degrees) between fill lines and the horizontal direction. 90 is the default value.

  thickness: Thickness of the fill lines representing the standard deviations. The field is defined as described for the THICKNESS optional parameter in Section 7.3.2. The thinnest possible line is the default.

  color: Color of the fill lines representing the standard deviations. The field is defined as described for the COLOR optional parameter in Section 7.3.2. The same color as the data is the default.

  linestyle: Style of the fill lines representing the standard deviations. The field is defined as described for the LINESTYLE optional parameter in Section 7.3.2. The default is a solid line.

  spacing: Distance in centimeters between each two neighbor fill lines. The default value is $\sim$0.15.

  If any of the above fields is absent or undefined, its default value is used.

- THRESHOLD_BSUM = *a numerical value*

  Threshold of the sum of the three magnetic components. The data resulting from the current data type or processing method are removed when the absolute value of the sum is lower than the threshold, i.e., when the signal is low. These data are represented in the same way as the data gaps. On a spectrogram this means that they are replaced by white regions. On a spectrum and on a time-series plot it corresponds to a discontinuity of the line connecting the data points. This parameter applies on all the data types except the power-spectral densities, the auto-power spectra and the Poynting flux. The default value is 5% of the total dynamic range above the minimum signal (in the logarithmic scale).

- THRESHOLD_ESUM = *a numerical value*

  Threshold of the sum of the electric components. The data resulting from the current data type or processing method are removed when the absolute value of the sum is lower than the threshold, i.e., when the electric signal is low. These data are represented as described for the THRESHOLD_BSUM optional parameter. The parameter THRESHOLD_ESUM applies on all the data types involving the

electric field except the power-spectral densities, the auto-power spectra and the Poynting flux. The default value is 5% of the total dynamic range above the minimum signal (in the logarithmic scale).

- THRESHOLD_ELIP = *a numerical value*

  Ellipticity threshold. The ellipticity is calculated using method ELL (see Section 4.3.2). The data resulting from the current data type or processing method are removed from places where the absolute value of the ellipticity is lower than the threshold, i.e., where the polarization is near to a linear one. These data are represented as described for the THRESHOLD_BSUM optional parameter. The parameter THRESHOLD_ELIP only applies to the following data types: THM, THS, THP, PHM, PHS, and PHP The default value of the ellipticity threshold is 0.2. The same parameter is used with all the SVD and SVDT methods to control the threshold of the ellipticity or electromagnetic planarity F_Z, respectively. The default value is 0.2.

- THRESHOLDS = *a string*

  This optional parameter serves to control the thresholds by an arbitrary combination of data types or processing methods. The data resulting from the main data type or processing method are removed according to the condition described by the string. The removed data are represented in the same way as the data gaps. On a spectrogram this means that they are replaced by white regions. On a spectrum and on a time-series plot it corresponds to a discontinuity of the line connecting the data points. This parameter applies on all the data types except the power-spectral densities and auxiliary data. In the definition string, definitions of particular conditions are separated by "&&". All data are considered as initially valid and then the string is evaluated from left to right. Each of the particular conditions has the following syntax:

  data type <space> *relation* <space> *threshold value*

  data type: any data type except the power-spectral densities and auxiliary data

  relation: one of the four following strings: INVALID_BELOW(the default) or INVALID_ABOVE or VALID_BELOW or VALID_ABOVE

  threshold value: any value; if absent the default value is zero (0).

- MAXREGERR = *a numerical value*

  This optional parameter controls the maximum acceptable relative error of time regularity (display of data gaps). The default value is 10%, and it has to be increased to large values if the user wants to interpolate larger data gaps instead of leaving empty spaces in the output figures.

- LOGDATA (switch)

  If this switch is present a logarithmic data axis (vertical axis for a spectrum or time series, color bar axis for a spectrogram) is created. The default type of the axis is automatically connected with the respective data type (for instance, logarithmic for power spectrograms, linear for the degree of polarization, cyclic for the azimuthal angle). The default type for the auxiliary data is a linear data axis.

- LINDATA (switch)

  If this switch is present a linear data axis is created and the default type of this axis is overridden (see above the explication for the switch LOGDATA).

- CYCDATA = *a numerical value*

AUTO	the minimum or the maximum value is found by an automatic inspection of all available data.
a numerical value	a user supplied definition of the minimum or maximum of plotted data.

Table 9: Definition of the data interval

If this parameter is present a cyclic data axis is created and the default type of this axis is overridden (see above the explication for the switch LOGDATA). Cyclic axis is a special type of the linear axis intended to be used for cyclic variables, like azimuthal angle. Its value φ in degrees is the same as $\varphi + 360k$ where $k = \ldots, -2, -1, 0, 1, \ldots$ In this case *a numerical value* would be equal to 360. Consequences of this parameter are a cyclic color scale for spectrograms (a rainbow starting by red and going through blue, green, and yellow, back to red), and a special procedure for connecting data points (shortest path) for spectra and time series.

- EARTHPHI (switch)

  If this switch is present, and if the Data type principal parameter starts by PH or E_PH a transformation of the ϕ (azimuthal) angle is done. It consists of rotation around the z axis of the basic coordinate system to get the x axis from the plane containing the sunward direction into the plane containing the anti-Earthward direction. This convention is more suitable for magnetospheric studies.

7.3.3. Panel size

Example:

```
Panel size:          2.
```

Vertical dimension of the panel. The value in centimeters is exactly reproduced on a POSTSCRIPT plot of the default width (A4 with 2cm margins in the portrait or landscape orientation). If the width is modified, the panel dimension is re-scaled by the same magnification factor as the figure width (see the WIDTH optional parameter in Section 7.2.2).

If the FORCEDHEIGHT optional parameter is set (Section 7.2.2), the panel size defines a relative dimension of the current panel with respect to the other panels.

If the panel size is less than 0.1% of the total page height, it is redefined to reach this value and a warning it printed:
`Warning: Panel size no. X is too small.`

For a raster file or screen output the dimension of the panel is calculated to obtain approximately the same layout as on the POSTSCRIPT plot.

7.3.4. Min data, Max data

Example:

```
Max data:           AUTO
Min data:           AUTO
```

These parameters define the minimum and the maximum of the data axis in the current panel. The data axis is the vertical axis of the panel in a spectrum and in a time-series plot, and the color-scale axis corresponding to that panel in the spectrogram mode. Both lines have two syntactic possibilities given in Table 9.

8. Conclusion

This document is based on the PRASSADCO version of 2003-Jun-21. The program can be downloaded from `ftp://canopus.cnrs-orleans.fr/pub/PRASSADCO/` or from `http://terezka.ufa.cas.cz/santolik/PRASSADCO/`. All the processing methods have been successfully tested with artificial data [e.g., *Santolík et al.*, 2000]. These data have been generated for waves with well defined propagation properties, taking into account dispersive properties of the plasma medium. Different methods may however have different sensitivity to experimental errors, especially to deformations induced by the on-board compression of the STAFF-SA data [see *Santolík*, 1993].

Although the program has also been tested with real data of the MEMO (INTERBALL), HFWR (POLAR), STAFF-SA and WBD (Cluster) devices, bugs may remain in some routines. The user should be careful when interpreting the results and the comparison of results of different methods may help to avoid possible misinterpretations.

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A. Appendices

A.1. Examples of overview figures

The first example shows the overview figures created from the script `n2` (see Section 6.5). This script runs PRASSADCO with three variants of the control file.

- Plot of auto-power spectra and power-spectral densities (see Figure 4).
- Plots of simple propagation parameters (see Figure 6).

The plots simultaneously represent the data of all four satellites. Figures 5 and 7 show examples of the resulting plots.

```
;-------------------------------------------------------------------------
;--- PRASSADCO (PRopagation Analysis of Staff-SA Data with COherency tests) ---
;---                    Control file v 2000Feb03                         ---
;---                                                                     ---
;-------------------------------------------------------------------------
File prefix:         /home/os/staff_sa/data/Co_001212_1_2a_*, REUSE ;
Output type:         PS, FORCEDHEIGHT=PAGE, CHARSIZE=7      ;
Plot type:           SPECTROGRAM, COMMENTS,COMMENTS_REL_SIZE=1.3,lineannotation=0.91&0.26&black&CLUSTER 1&10&&0.91&0.24&red ...
Min time:            AUTO                      ;
Max time:            2000-12-12T15:03:58.656                     ;
Min frequency:       AUTO                      ;
Max frequency:       AUTO                      ;
Orbit information:   UT  XGSE YGSE ZGSE SC_DR1_XYZ_GSE1 SC_DR1_XYZ_GSE2 SC_DR1_XYZ_GSE3 SC_DR2_XYZ_GSE1 SC_DR2_XYZ_GSE2 ...
Title (top):  CLUSTER STAFF-SA!8  %t1 - %t2!3,rel_size=2.   ;
Title (bottom):%lf%lfAll data from %c3.%lf!8%c2%lf!3Plot created %now by %ver.   !8 ORBIT No. %SC_ORBIT_NUM!3,rel_size=1.1;
;-----------------------------------------------
Data source:         1                        ;
Data type:           PSD_Bsum,comment=CLUSTER 1%lf%def,title=B (nT!u2!n/Hz)                    ;
Panel size:          2.                       ;
Min data:            1e-10                     ;
Max data:            1e-4                   ;
;-----------------------------------------------
Data source:         1                        ;
Data type:           bxc1 ,overplot,use_int,color=white,avepoints=500,function=sqrt(bxc1^2+byc1^2+bzc1^2)*28., title=,comment=;
Panel size:          2.                       ;
Min data:            0.1                       ;
Max data:            100                      ;
;-----------------------------------------------
Data source:         2                        ;
Data type:           PSD_Bsum ,comment=CLUSTER 2%lf%def,title=B (nT!u2!n/Hz)                   ;
Panel size:          2.                       ;
Min data:            1e-10                     ;
Max data:            1e-4                     ;
;-----------------------------------------------
Data source:         2                        ;
Data type:           bxc2 ,overplot,use_int,color=white,avepoints=500,function=sqrt(bxc2^2+byc2^2+bzc2^2)*28., title=,comment=;
Panel size:          2.                       ;
Min data:            0.1                       ;
Max data:            100                      ;
;-----------------------------------------------
Data source:         3                        ;
Data type:           PSD_Bsum ,comment=CLUSTER 3%lf%def,title=B (nT!u2!n/Hz)                   ;
Panel size:          2.                       ;
Min data:            1e-10                     ;
Max data:            1e-4                     ;
;-----------------------------------------------
Data source:         3                        ;
Data type:           bxc3 ,overplot,use_int,color=white,avepoints=500,function=sqrt(bxc3^2+byc3^2+bzc3^2)*28., title=,comment=;
Panel size:          2.                       ;
Min data:            0.1                       ;
Max data:            100                      ;
;-----------------------------------------------
Data source:         4                        ;
Data type:           PSD_Bsum ,comment=CLUSTER 4%lf%def,title=B (nT!u2!n/Hz)                    ;
Panel size:          2.                       ;
Min data:            1e-10                     ;
Max data:            1e-4                     ;
;-----------------------------------------------
Data source:         4                        ;
Data type:           bxc4 ,overplot,use_int,color=white,avepoints=500,function=sqrt(bxc4^2+byc4^2+bzc4^2)*28., title=,comment=;
Panel size:          2.                       ;
Min data:            0.1                       ;
Max data:            100                      ;
;-----------------------------------------------
Data source:         1                        ;
Data type:           PSD_Esum,comment=CLUSTER 1%lf%def,title=E (mV!u2!n/m!u2!n/Hz)                  ;
Panel size:          2.                       ;
Min data:            3e-10                     ;
Max data:            1e-3                     ;
;-----------------------------------------------
Data source:         1                        ;
Data type:           bxc1 ,overplot,use_int,color=white,avepoints=500,function=sqrt(bxc1^2+byc1^2+bzc1^2)*28., title=,comment=;
Panel size:          2.                       ;
Min data:            0.1                       ;
Max data:            100                      ;


......
```

Figure 4: Control file `auto_pra.ini` (default overview plots of power spectra)

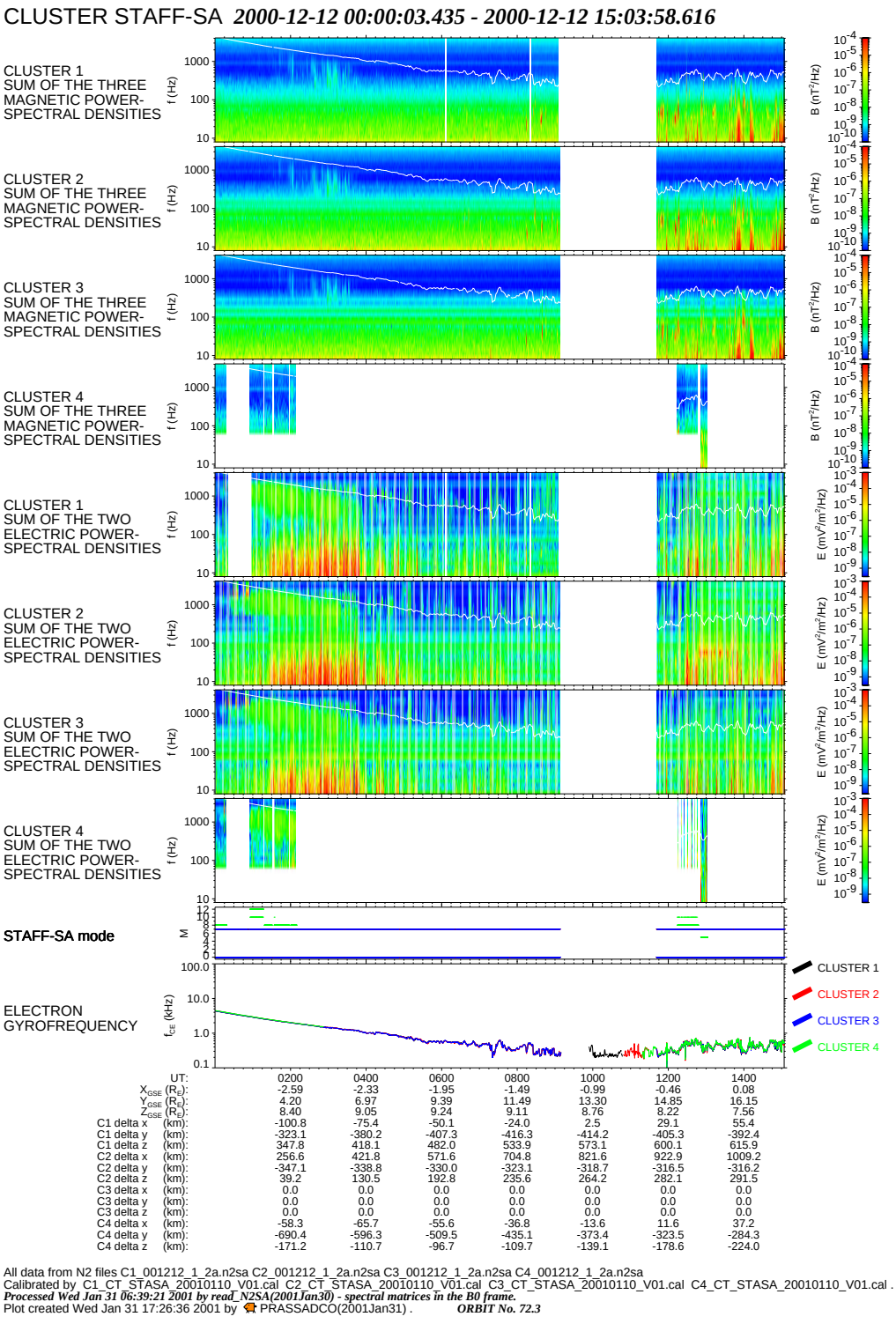

Figure 5: Example of an overview plot of power spectra

```
;------------------------------------------------------------------------
;--- PRASSADCO (PRopagation Analysis of Staff-SA Data with COherency tests) ---
;---                    Control file v 2000Feb03                        ---
;---                                                                    ---
;------------------------------------------------------------------------
File prefix:         /home/os/staff_sa/data/Co_001212_2_2a_*, REUSE ;
Output type:         PS, FORCEDHEIGHT=PAGE, CHARSIZE=7      ;
Plot type:           SPECTROGRAM, COMMENTS,COMMENTS_REL_SIZE=1.3,lineannotation=0.91&0.26&black&CLUSTER 1&10&&0.91&0.24&red  ...
Min time:            AUTO                      ;
Max time:            2000-12-12T15:03:58.656                    ;
Min frequency:       AUTO                      ;
Max frequency:       AUTO                      ;
Orbit information:   UT XGSMC3 YGSMC3 ZGSMC3;
Title (top):  CLUSTER STAFF-SA!8  %t1 - %t2!3,rel_size=2.   ;
Title (bottom):%lf%lfAll data from %c3.%lf!8%c2%lf!3Plot created %now by %ver.  !8 ORBIT No. %SC_ORBIT_NUM!3,rel_size=1.1;
;-----------------------------------------------
Data source:         1                        ;
Data type:           EIGEN,THRESHOLD_BSUM =-1 ,comment=CLUSTER 1%lf%def                     ;
Panel size:          2.                       ;
Min data:            0.333                      ;
Max data:            1.                       ;
;-----------------------------------------------
Data source:         1                        ;
Data type:           bxc1 ,overplot,use_int,color=black,avepoints=500,function=sqrt(bxc1^2+byc1^2+bzc1^2)*28., title=,comment=;
Panel size:          2.                       ;
Min data:            0.1                       ;
Max data:            100                      ;
;-----------------------------------------------
Data source:         2                        ;
Data type:           EIGEN,THRESHOLD_BSUM =-1 ,comment=CLUSTER 2%lf%def                     ;
Panel size:          2.                       ;
Min data:            0.333                      ;
Max data:            1.                       ;
;-----------------------------------------------
Data source:         2                        ;
Data type:           bxc2 ,overplot,use_int,color=black,avepoints=500,function=sqrt(bxc2^2+byc2^2+bzc2^2)*28., title=,comment=;
Panel size:          2.                       ;
Min data:            0.1                       ;
Max data:            100                      ;
;-----------------------------------------------
Data source:         3                        ;
Data type:           EIGEN,THRESHOLD_BSUM =-1 ,comment=CLUSTER 3%lf%def                     ;
Panel size:          2.                       ;
Min data:            0.333                      ;
Max data:            1.                       ;
;-----------------------------------------------
Data source:         3                        ;
Data type:           bxc3 ,overplot,use_int,color=black,avepoints=500,function=sqrt(bxc3^2+byc3^2+bzc3^2)*28., title=,comment=;
Panel size:          2.                       ;
Min data:            0.1                       ;
Max data:            100                      ;
;-----------------------------------------------
Data source:         4                        ;
Data type:           EIGEN,THRESHOLD_BSUM =-1 ,comment=CLUSTER 4%lf%def                     ;
Panel size:          2.                       ;
Min data:            0.333                      ;
Max data:            1.                       ;
;-----------------------------------------------
Data source:         4                        ;
Data type:           bxc4 ,overplot,use_int,color=black,avepoints=500,function=sqrt(bxc4^2+byc4^2+bzc4^2)*28., title=,comment= ;
Panel size:          2.                       ;
Min data:            0.1                       ;
Max data:            100                      ;
;-----------------------------------------------
Data source:         1                        ;
Data type:           ELL,THRESHOLD_BSUM =-1 ,comment=CLUSTER 1%lf%def                      ;
Panel size:          2.                       ;
Min data:            -1.                      ;
Max data:            1.                       ;


.....
```

Figure 6: Control file `cross1_pra.ini` (first part of simple propagation characteristics)

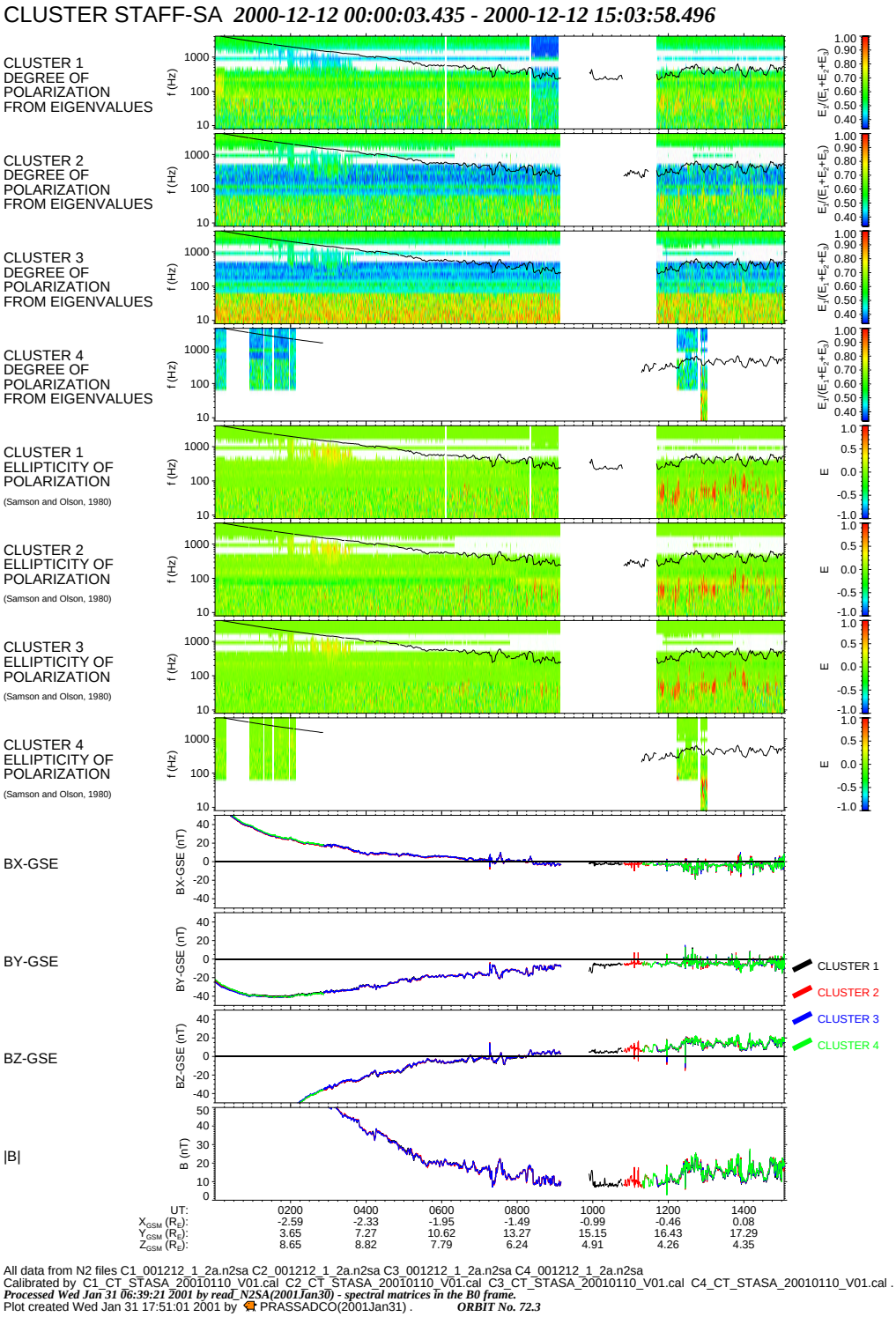

Figure 7: Example of an overview plot of propagation characteristics

A.2. Examples of detailed figures

The PRASSADCO standard output shown in Figure 1 in Section 3 is produced using the control file presented in Figure 8. The corresponding graphic output is shown in Figure 9.

```
;------------------------------------------------------------------------------
;--- PRASSADCO (PRopagation Analysis of Staff-SA Data with COherency tests) ---
;---                    Control file v 2000Feb03                              ---
;---                                                                          ---
;------------------------------------------------------------------------------
File prefix:         $HOME/staff_sa/data/Co_991117/Co_991117_1_1a
Output type:         PS
Plot type:           spectrogram, lineannotation=0.5&0.85&blue& annotation
Min time:            1999-11-17 13:30:00
Max time:            1999-11-17 13:45:00
Min frequency:       auto
Max frequency:       auto
Orbit information:   UT XGSE YGSE ZGSE DC_BX
Title (top):         !4%c1!3%lf%t1 - %t2, horizpos=0
Title (bottom):
;-----------------------------------------------
Data source:         -1
Data type:           bsum,average,color=blue,thickness=5, title=B!dsum!n (nT)
Panel size:          4.
Min data:            AUTO
Max data:            AUTO
;-----------------------------------------------
Data source:         -1                      ;
Data type:           thsvdtf,tickvalues=0&45&90&135&180,minorticks=9,tave=5
Panel size:          4.                      ;
Min data:            0.                    ;
Max data:            180.                    ;
;-----------------------------------------------
Data source:         -1                      ;
Data type:           ANTDIRX1,symbol=10,function=sqrt(ANTDIRX1^2+ANTDIRY1^2), title=sin !Mb!3!d1!n ;
Panel size:          2.                    ;
Min data:            0.                    ;
Max data:            1.1                     ;
```

Figure 8: Example of a user-defined control file

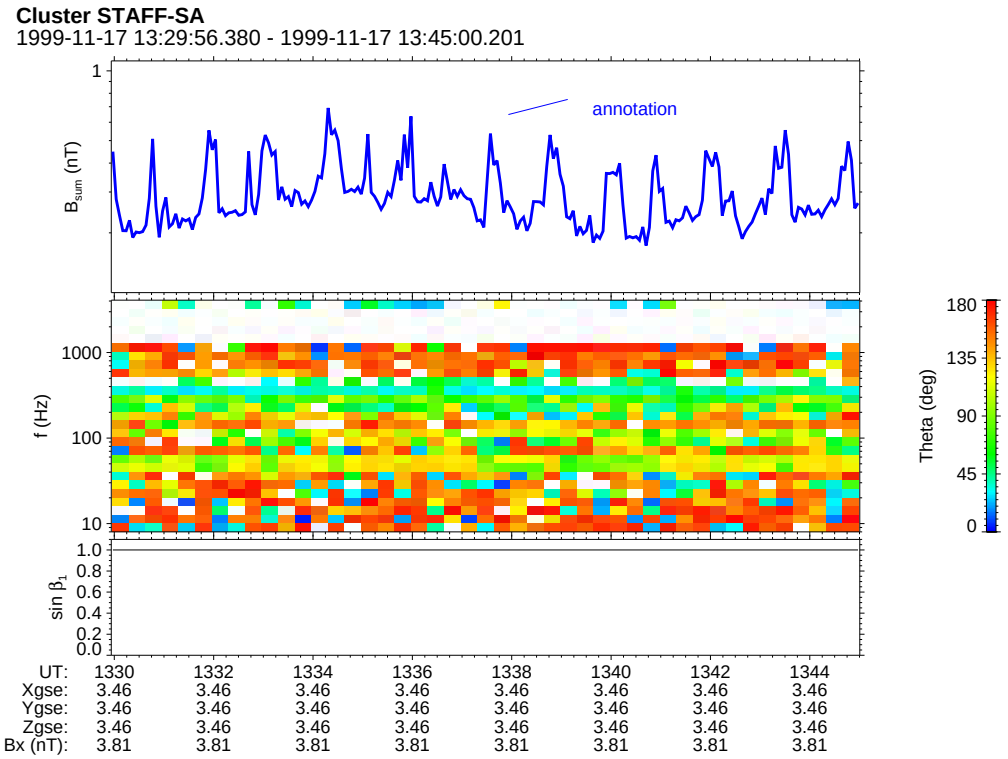

Figure 9: Example of a spectrogram combined with a time series plot

A.3. Examples of "Primary parameter" and "Summary parameter" files

The last example shows the processing of the "Primary parameter" and "Summary parameter" data from the CDF files. Figure 10 contains a control file of the `read_N2SA` procedure described in Section 6.4. Figure 11 shows the standard output of this procedure. Note that the "N2" file `/home/santolik/staff_SA/other/selatko.n2sa` does not exist and only auxiliary data are saved. Figure 12 contains a PRASSADCO control file, Figure 13 shows the corresponding standard output, and, finally, Figure 14 shows the resulting plot.

```
;------------------------------------------------------------------------------
;---  read_N2SA - reading of Staff-SA (Cluster mission) N2 calibrated data  ---
;---                    Control file v 2001JAN25                            ---
;---                                                                        ---
;------------------------------------------------------------------------------
N2 file name  :         $HOME/other/selatko.n2sa ; a_comment
Memory limit (MBytes) : 20
CL_SP_AUX file name :   $HOME/staff_sa/other/CL_SP_AUX_20000113_V00.cdf
C1_PP_(FGM) file name :
C2_PP_(FGM) file name :
C3_PP_(FGM) file name : $HOME/staff_sa/other/C3_PP_19960131_V01.cdf
C4_PP_(FGM) file name :
```

Figure 10: Control file `sele.ini` for reading the test auxiliary data

```
IDL> read_N2SA,'sele.ini'
------------------------------------------------------------------------
----  read_N2SA - reading of Staff-SA (Cluster) N2 calibrated data  ----
------------------------------------------------------------------------
 Started Fri Apr 14 15:26:25 2000   version (2000Apr13)
 Reading ini file sele.ini
 Writing LOG file /home/santolik/staff_sa/other/selatko_log.txt
N2 file /home/santolik/staff_SA/other/selatko.n2sa not found.
No SM records found.
No PSD records found.
Reading CDF file /home/santolik/staff_sa/other/CL_SP_AUX_20000113_V00.cdf
Reading CDF file /home/santolik/staff_sa/other/C3_PP_19960131_V01.cdf

****************************************
*** Saving /home/santolik/staff_SA/other/selatko_aux.dat
****************************************
IDL>
```

Figure 11: Standard output of the `read_N2SA` procedure reading the test auxiliary data

```
;------------------------------------------------------------------------------
;--- PRASSADCO (PRopagation Analysis of Staff-SA Data with COherency tests) ---
;---                    Control file v 2000Feb03                            ---
;---                                                                        ---
;------------------------------------------------------------------------------
File prefix:         $HOME/staff_sa/other/selatko
Output type:         ps, FORCEDHEIGHT=PAGE ,charsize=11
Plot type:           series, comments, SOURCE=-1
Min time:            auto
Max time:            auto
Min frequency:       auto
Max frequency:       auto
Orbit information:   UT SC_R_XYZ_GSE1 SC_R_XYZ_GSE2 SC_R_XYZ_GSE3
Title (top):         %t1 - %t2, horizpos=0.35
Title (bottom):      %lf%lfPlot created %now by %ver.,rel_size=0.7,horizpos=0.1
;---------------------------------------------
Data source:         -1
Data type:           bxc3, color=red, rectangle=&0& &0, title=B!dX!n (nT)
Panel size:          1.
Min data:            AUTO
Max data:            AUTO
;---------------------------------------------
Data source:         -1
Data type:           byc3, color=blue, title=B!dY!n (nT) ; a text
Panel size:          1.
Min data:            AUTO
Max data:            AUTO
;---------------------------------------------
Data source:         -1
Data type:           bzc3, color=violet, title=B!dZ!n (nT) ; another text
Panel size:          1.
Min data:            AUTO
Max data:            AUTO
;---------------------------------------------
Data source:         -1
Data type:           SELATKO ; another text
Panel size:          1.
Min data:            AUTO
Max data:            AUTO
```

Figure 12: Control file `selatko.ini` for plotting the test auxiliary data

```
IDL> pra,'selatko.ini'
-------- PRASSADCO(2000Jun26) started Wed Jun 28 18:24:00 2000
   ...file $HOME/staff_sa/other/selatko_sm.dat not found.
 Invalid spectral matrix data (input)
 No input data.
 No electric antenna found.
   ...file $HOME/staff_sa/other/selatko_psd.dat not found.
 Power-spectral density of 0 components.
   ...restoring data from /home/santolik/staff_sa/other/selatko_aux.dat
 51 AUX tags   MODE SC_STATUS1 SC_STATUS2 SC_STATUS3 SC_STATUS4 SC_STATUS5
 SC_ORBIT_NUM SC_R_XYZ_GSE1 SC_R_XYZ_GSE2 SC_R_XYZ_GSE3 SC_V_XYZ_GSE1 SC_V_XYZ_GSE2
 SC_V_XYZ_GSE3 SC_DR1_XYZ_GSE1 SC_DR1_XYZ_GSE2 SC_DR1_XYZ_GSE3 SC_DR2_XYZ_GSE1
 SC_DR2_XYZ_GSE2 SC_DR2_XYZ_GSE3 SC_DR3_XYZ_GSE1 SC_DR3_XYZ_GSE2 SC_DR3_XYZ_GSE3
 SC_DR4_XYZ_GSE1 SC_DR4_XYZ_GSE2 SC_DR4_XYZ_GSE3 SC_AT1_LAT SC_AT1_LONG SC_AT2_LAT
 SC_AT2_LONG SC_AT3_LAT SC_AT3_LONG SC_AT4_LAT SC_AT4_LONG SC_CONFIG_QG SC_CONFIG_QR
 SC_DR_MIN SC_DR_MAX GSE_GSM DIPOLE_TILT SC_GEOM_SIZE SC_GEOM_ELONG
 SC_GEOM_PLANARITY SC_GEOM_E_DIR_GSE1 SC_GEOM_E_DIR_GSE2 SC_GEOM_E_DIR_GSE3
 SC_GEOM_P_NOR_GSE1 SC_GEOM_P_NOR_GSE2 SC_GEOM_P_NOR_GSE3 BXC3 BYC3 BZC3
 ----------------------------------------
 Available Data Types:  MODE SC_STATUS1 SC_STATUS2 SC_STATUS3 SC_STATUS4 SC_STATUS5
 SC_ORBIT_NUM SC_R_XYZ_GSE1 SC_R_XYZ_GSE2 SC_R_XYZ_GSE3 SC_V_XYZ_GSE1 SC_V_XYZ_GSE2
 SC_V_XYZ_GSE3 SC_DR1_XYZ_GSE1 SC_DR1_XYZ_GSE2 SC_DR1_XYZ_GSE3 SC_DR2_XYZ_GSE1
 SC_DR2_XYZ_GSE2 SC_DR2_XYZ_GSE3 SC_DR3_XYZ_GSE1 SC_DR3_XYZ_GSE2 SC_DR3_XYZ_GSE3
 SC_DR4_XYZ_GSE1 SC_DR4_XYZ_GSE2 SC_DR4_XYZ_GSE3 SC_AT1_LAT SC_AT1_LONG SC_AT2_LAT
 SC_AT2_LONG SC_AT3_LAT SC_AT3_LONG SC_AT4_LAT SC_AT4_LONG SC_CONFIG_QG SC_CONFIG_QR
 SC_DR_MIN SC_DR_MAX GSE_GSM DIPOLE_TILT SC_GEOM_SIZE SC_GEOM_ELONG
 SC_GEOM_PLANARITY SC_GEOM_E_DIR_GSE1 SC_GEOM_E_DIR_GSE2 SC_GEOM_E_DIR_GSE3
 SC_GEOM_P_NOR_GSE1 SC_GEOM_P_NOR_GSE2 SC_GEOM_P_NOR_GSE3 BXC3 BYC3 BZC3
 ----------------------------------------
   ...plotting bxc3
   ...plotting byc3
   ...plotting bzc3
   ...plotting SELATKO
 Unknown data type: SELATKO.
-------- PRASSADCO(2000Jun26) done    Wed Jun 28 18:24:16 2000
IDL>
```

Figure 13: Standard output of PRASSADCO when plotting the test auxiliary data

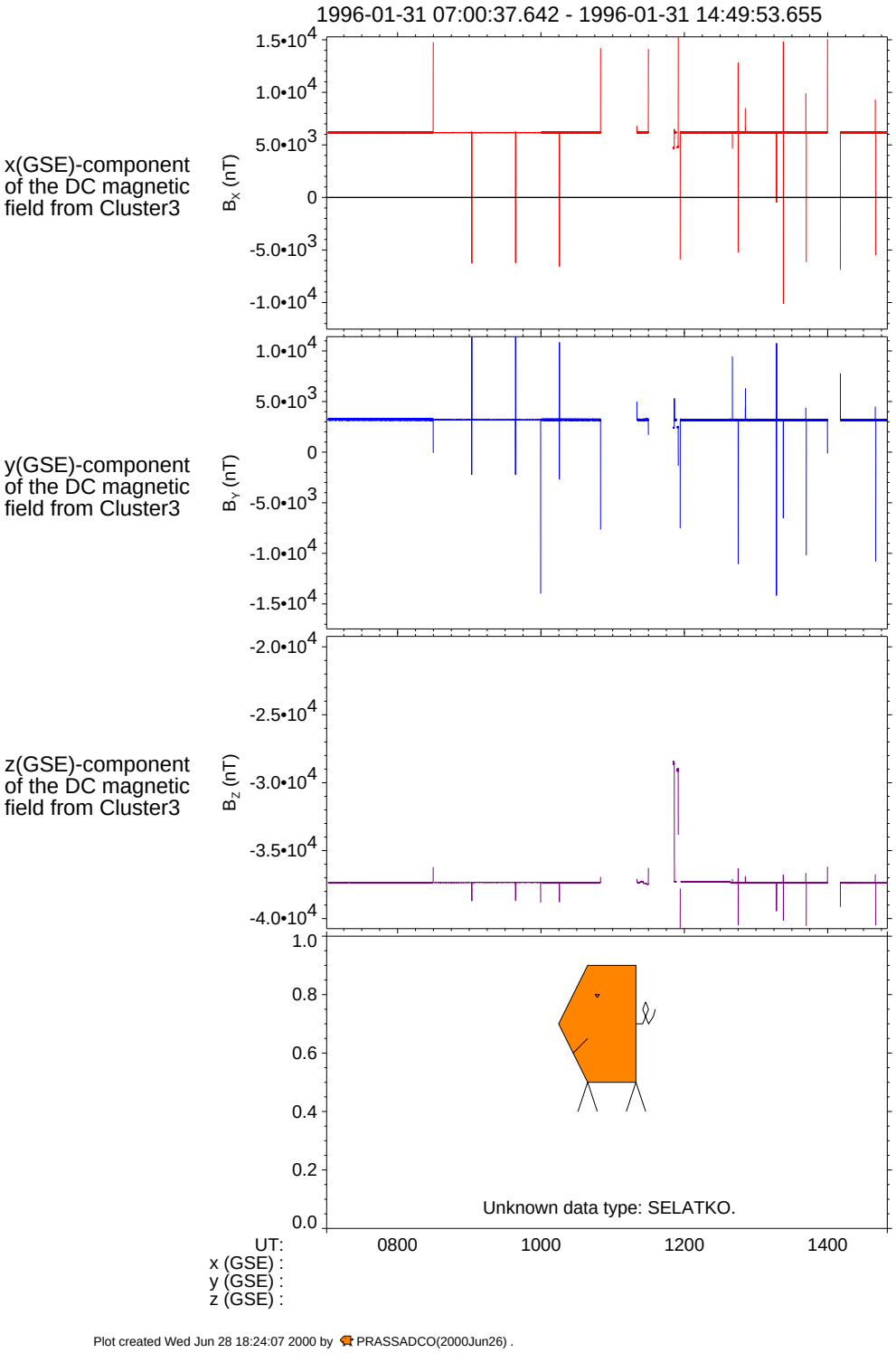

Figure 14: A plot of test auxiliary data