Chapter II

Data processing

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Summary

The satellite data are acquired by the DSN and undergo various processing operations. In particular, the CDHF produces the zero level data and the key parameters. The zero level data, the data in CDF format are repatriated from the GSFC or are obtained on CD/ROMs. The data of the other experiments (key parameters) as well as the orbital data are obtained as CDF files (standard ISTP format). The telemetry rate for the Waves experiment is 936.96 bps at low rate and twice that at high rate. At the satellite level, the telemetry data are organized in Major Frame and Minor Frame (1 MF = 250 mf). At the Waves experiment level, the DPU manufactures 431-byte packets that are placed in a MF. The Waves data are accessed through the WIND/Waves software library. At this level, the data for each instrument is seen as a succession of events, one event generally corresponding to one cycle of instrument measurements. This library also provides access to key parameters and orbital data. Some examples of programs using the software library are presented. The principle is based on calling procedures with the desired data type ("item") as the call argument and the data values as the return argument. Technical details on data access and the system environment are given in Appendix II.

Content

2. Data processing

2.1. Organization and data flow

From the moment the data is sent by satellite to the moment it is used in the laboratories, the data undergoes a number of manipulations.

- The telemetry data sent by the satellite is received on the ground by the DSN[1] (Deep Space Network), which also transmits the remote controls to the satellite.

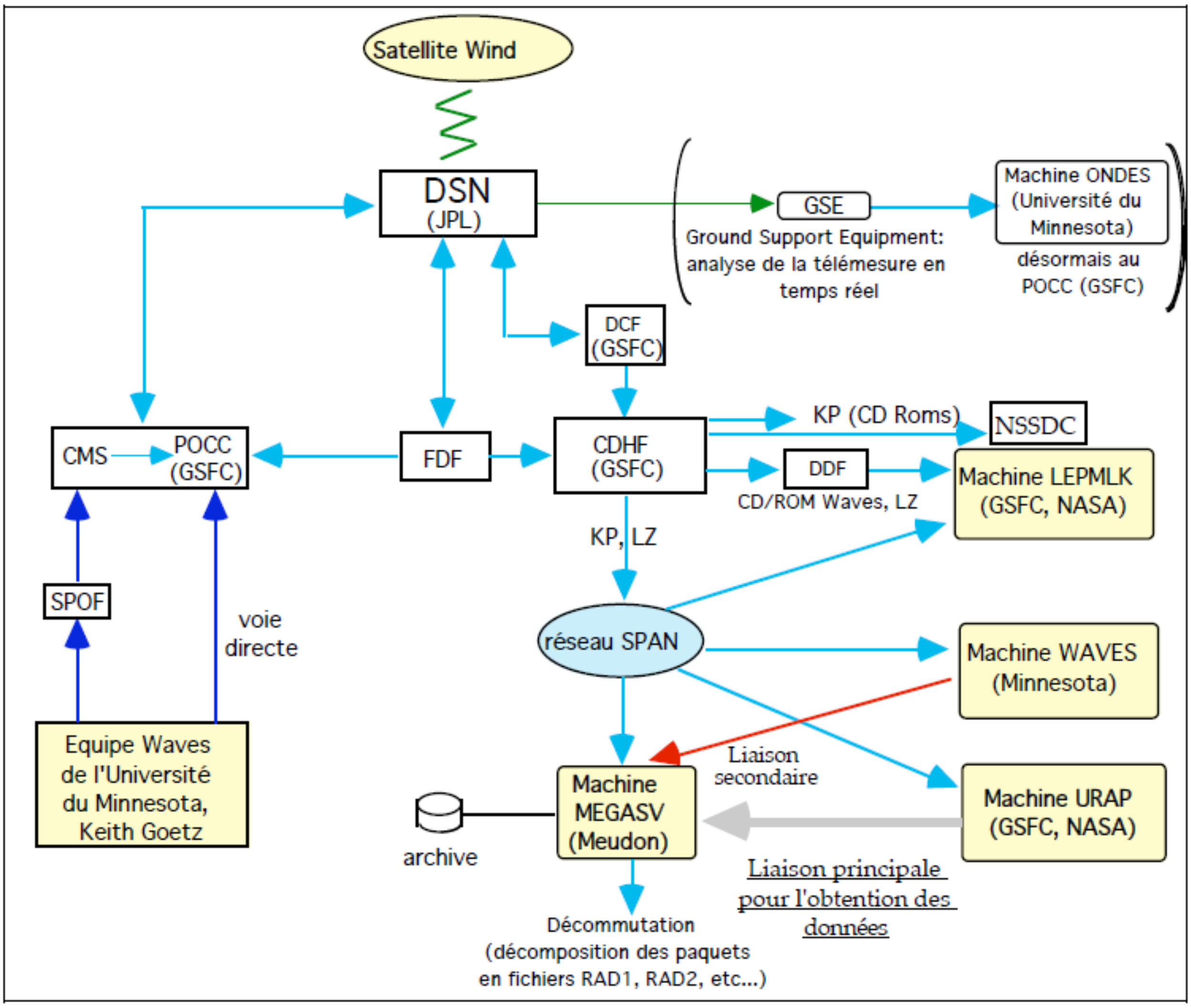

Fig. Waves data flow diagram

All command and data processing operations (command, control, orbit and attitude calculation, mission analysis, acquisition and processing) are conducted at the Goddard Space Flight Center (GSFC) [MIS].

- At the GSFC, the Data Capture Facility (DCF) separates (decomposes) the raw telemetry data flow from the DSN into a separate data flow for each experiment (Zero Level data) and an auxiliary data flow containing housekeeping (HK) information. The Zero Level data, satellite orbital and attitude parameters are transferred electronically to the CDHF via high-speed networks (NASCOM networks).

[1] Cf. glossary

- The CDHF (Central Data Handling Facility) records, catalogues and organises the data. The CDHF provides on-line access to various data: Zero Level data, quicklook, orbit, attitude, KP. One of its essential functions is the generation of key parameters: "Key Parameters" or KP[2]. The DDF (Data Distribution Facility) receives and organizes the CDHF products, and creates the different media (CD/ROM, etc..) which are sent to the IPs in the different space laboratories. The CDHF is an original component of the GGS program: it processes, stores and distributes GGS data to the IPs in a fast and economical way.

- The Science Planning and Operation Facilities (SPOF) is the ground-based GGS component responsible for planning the science operations of the ISTP program, under the direction of the ISTP project scientist (M.H. Acuna). This structure, composed of a team of scientists, is the point of contact between the program and the scientific managers. The SPOF[3] assists the FOT (Flight operation Team) in planning scientific operations. The SPOF assists the ISTP investigators in identifying time intervals suitable for detailed analysis. To accomplish this task, the SPOF staff reviews the KPs and reports any anomalies or events of interest to the appropriate investigator. The SPOF reviews the remote controls from the KPs to identify and resolve any instrumental conflicts. It coordinates the scientific operations, and monitors the quality of the KP. Once this is done, the results are sent to the POCC (Project Operation Control Center) where the final remotes are assembled.

- A dedicated command management system, the Command Management System: CMS, is located at the POCC, GSFC, and managed by FOT. The CMS is the interface with the POCC for science operations planning and remote controls. In the case of the Waves team, the remote controls are passed to P.I. Mike Kaiser who passes them on to the POCC. There, the commands are "assembled" for delivery to the satellite at the appropriate times.

- The Flight Dynamics Facility (FDF) performs attitude and orbit calculations, maneuver prediction, etc. .... The predicted and final orbit and attitude data are transmitted to the CDHF (TBV).

- The IPs in the various laboratories have their own computerized analysis facilities: RDAF (Remote Data Analysis Facilities).

For more details on the organization of WIND data, and ISTP in general, see publication [].

Note: The ONDES computer that was used for the satellite tests in the United States is now located at the POCC in Goddard. It is accessible through SPAN under the name ONDES. This computer, directly connected to the telemetry stream, was used for near-real-time (NRT) data processing during the start-up phase of the experiments. Since then, real-time access to the telemetry flow is possible via a network. This is only possible when the DSN is in direct contact with the WIND probe, i.e. about two hours per day.

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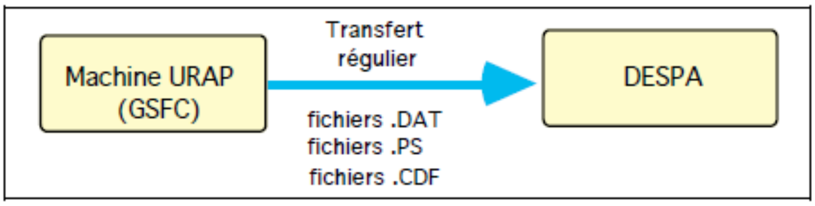
[2] At the CDHF, the Key Parameter Generation Software (KPGS) uses the Zero Level data to generate the key parameters. These are summarized data that serve as a sort of index to guide the search of the data. They are, in general, low resolution time series. They reflect the characteristic geophysical parameters of each experiment. Care should be taken that the key parameters are not calibrated and that they use predicted orbit data. Their advantage is that they are available very quickly after the reception of the ground data.

[3] The SPOF identifies times when the configuration of the ISTP satellites is optimal for particular studies, such as May 9/10, 1996 for substorm studies when WIND and GEOTAIL crossed the magnetotail simultaneously while IMP8 observed the solar wind. SPOF has developed a number of data visualization tools to assist in planning operations. These are available to the scientific community at the WEB address: http://www-spof.gsfc.nasa.gov. On this server, a member of the scientific community can submit a "SPOT" (Science Planning Operation Topic) for specific scientific operations.

2.2. Data acquisition

Data files from the Waves experiment are regularly copied from the CDHF to the URAP machine at the GSFC. These are Level Zero Data files, postscript files and CDF files.



Zero level and postscript files

- The zero level .DAT files on the URAP[4] machine are copied to the DESPA at the level of the directory WIND_1:[WIND.CDHF.LZ.WAVES.9502]. It was decided to create one subdirectory per month[5] . Their nomenclature is of the type:

  WI_LZ_WAV_19950215_V01.DAT;1

- Similarly, the .PS files in postscript[6] format are copied to DESPA in the WIND_1:[WIND.POSTSCRIPT] directory. These files in postscript[7] format are:

  - daily summary plots in grayscale (an example of a summary plot is presented at the end of the chapter). They include two pages per day, the first one concerning Waves-1,the second Waves-2. Their nomenclature is of the type:

  WI_P1_WAV_19950109_V01.PS;1 WI_P2_WAV_19950109_V01.PS;3

  - possibly the dynamic spectra (color postscript files) for RAD1, RAD2 and TNR, which are also produced at DESPA (C. Perche programs). Their nomenclature is of the type:

  RAD1_S_19960703.PS;1 RAD2_S_19961025.PS; 1TNR_19960727.PS;1

Files in CDF format

Similarly, files in CDF format (see above) are copied to DESPA from the [] directory. They contain:

- orbit, attitude and spin phase information of the satellite.

[4] These files are located in the URAP::DATA_L:[WIND_DATA.CDHF.WAVES] directory or in short: URAP::WIND_DATA_ROOT:[CDHF.WAVES]

[5] This monthly organization is likely to change in favor of a single directory containing all the data. In the longer term, it is envisaged to install a file server machine or a RAID disk type solution.

[6] These files are located in the URAP::DATA_L:[WIND.POSTSCRIPT] directory or in short: URAP::WIND_PS:

[7] The images can be visualized using the Quickview software tool developed by the CNES [CAR]. It allows the search of files according to different criteria, the visualization, the analysis by means of different tools: magnifying glass, zoom, scrolling etc..., and the printing of the plots. This recent technique replaces conventional methods of visualizing dynamic spectra, such as those using microfiche. At DESPA, this software is installed on the Calypso machine.

- the key parameters of some WIND experiments (MFI, 3DP, SWE, WAVES).

CD/ROM support

- DESPA receives CD/ROMs containing level zero data from CDHF once a month, with a one or two month delay. The nomenclature of the CD/ROMs is as follows:

  USA-NASA-DDF-WI-WAVES-LZ-001 (= CD/ROM #1)
  USA-NASA-DDF-WI-WAVES-LZ-002 (= CD/ROM #2)
  USA-NASA-DDF-WI-WAVES-LZ-003 (= CD/ROM #3)
  etc...

- DESPA also receives CD/ROMs (mailed monthly) containing key parameters and ancillary data.

Remarks

- Online data

An application[8] at CDHF, built on a graphical interface (SQL*forms) using the Oracle DBMS, allows the selection of the desired data [WHI94]. This method is competitive with the method of copying files from the URAP machine to the DESPA. For a first use, a quick description of this interface is given in appendix 8.

- Switching to physical quantities

Procedures in the WIND/Waves software library allow the conversion of zero level data into physical quantities.

- Remote control history

The command history is not currently available in an explicit form. Indeed, there are two ways to send commands to the satellite: one can send the commands to a stored command table, which is the case most of the time, or in real time. The two corresponding traces must therefore be consulted. An implementation of this functionality in the WIND/Waves software library is envisaged. However, the summary plots already contain some information about the mode changes of the various Waves instruments. The "items" in the WIND/Waves software library provide the most complete information.

2.3. Telemetry

2.3.1. Telemetry format. Events - packages

The conventional fixed telemetry format used by the satellite is the Major Frame: MF[9]. The telemetry consists of a succession of such MFs. Each MF consists of 250 minor frames (mf). The general structure of an MF is given at the end of this chapter. The times given below assume a telemetry rate of LBR. In this case, the MF lasts 92 seconds. In HBR, it lasts half as long, i.e. 46 seconds.

1 MF	250 mf (0-249)

[8] set host istp and launch CDHF_UI. This application requires an account to be opened.

[9] The themes developed in this chapter are extracted from various software documentations due to Cathie Meetre, among others, to which one can also refer [MEE]. One can also consult with profit the documentation associated with the WIND library as already mentioned.

1 mf	256 words (0-255) including 237 words "science" (columns 19 to 255) and 19 words of HK (columns 0 to 18).
Length of a telemetry word	8 bits.
Duration of a probe rotation	3 seconds: in fact, 60 / 19.38 = 3.096 s
Duration of a MF	92 seconds (about 30 rotations).
Duration of a mf	0.368 seconds (92/250) or about 3 mf per second.

At standard telemetry rates (§ 2-3-3), the composition of the data transmitted to telemetry by the Waves experiment can be variable: the DPU constructs fixed-length packets (431 words) from the data coming from different parts of the experiment. Thus, the Waves words of most interest at a given time can be put into a packet. This "packetized" telemetry system allows flexibility in data handling both in flight and on the ground. The TNR instrument is an example of an instrument that can benefit from this possibility (see TNR packet composition).

The Waves experiment is allowed 10850 = 10775 + 75 words per FM. These 10850 words are organized into 431 data words every 10 mf, i.e. 431 x 250/10 = 10775 words, for each MF, as well as 75 housekeeping words per MF. The Waves experiment thus has 25 data packets per FM.

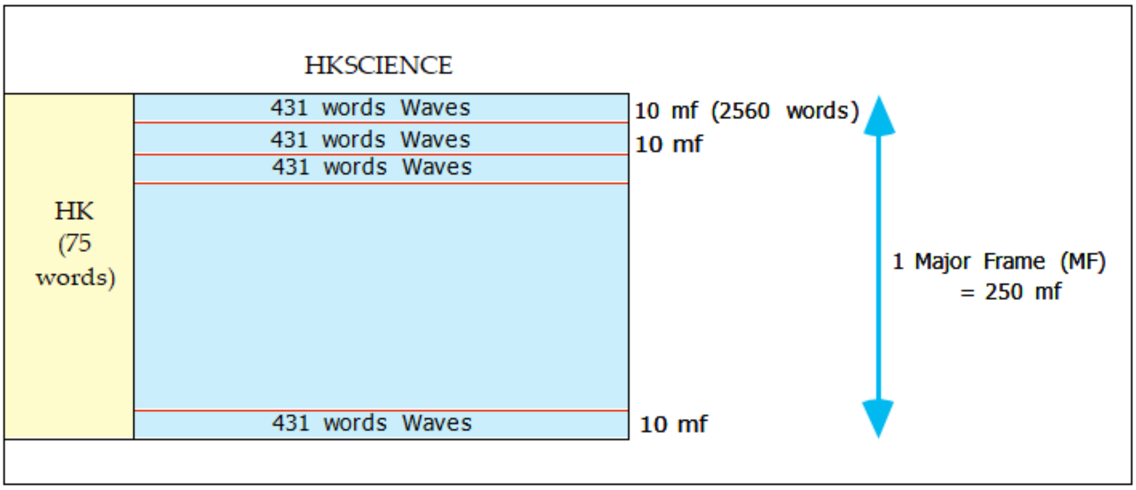
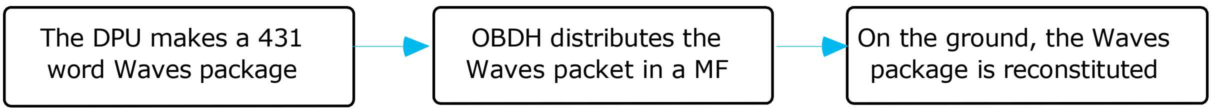


Fig. Simplified structure of a Major Frame (see also a more detailed diagram below)

The OBDH[10] distributes the words of the WAVES packets into an FM at fixed locations reserved for the WAVES experiment. The MF is transmitted to the ground where the 431-word Waves packets are reconstructed.



A Waves packet always contains a first header that identifies and delimits it, and possibly other headers following it that describe its contents. These headers thus allow the identification and sequencing of packets.

The first header contains the packet identifier, the "packet ID" which identifies the instrument: this identifier is 1 for RAD1, 2 for RAD2, 3 for TNR, etc., and the packet subtype which identifies the particular type of packet it is: for example a calibration packet. This first header also contains "flags" to indicate the possible presence of

[10] The "On Board Data Handling" (OBDH) is an electronic device on the satellite that collects data from the various on-board experiments, structures them and transmits them to the telemetry.

other headers in the packet.

We describe in § 4-10-2 the case of the TNR package.
The packages are the same size. However, the suitable packet size for an instrument may be shorter. The TDS instrument has its own telemetry allocation, but most of this comes from the space left over from packets not completely filled by other instruments. Any available space in a packet is thus used by the TDS instrument. In the packet header it is indicated whether the packet contains TDS information or not. This additional TDS data is also collected in events (see below).
An "event" consists of one or more packages: some instruments require only one package, while others require several. An event contains a complete measurement cycle for an instrument[11]. Housekeeping data is formally considered here in the same way as an instrument. Standard Waves events are referred to as such:

FFTL	Low band FFT,
FFTM	FFT Medium band
FFTH	FFT High band
TDSF	Time Domain Sampler Fast
TDSS	Time Domain Sampler Slow
TNR	Thermal Noise Receiver
RAD1	Lower Frequency Radio Receiver
RAD2	Higher Frequency Radio Receiver
HK	Housekeeping

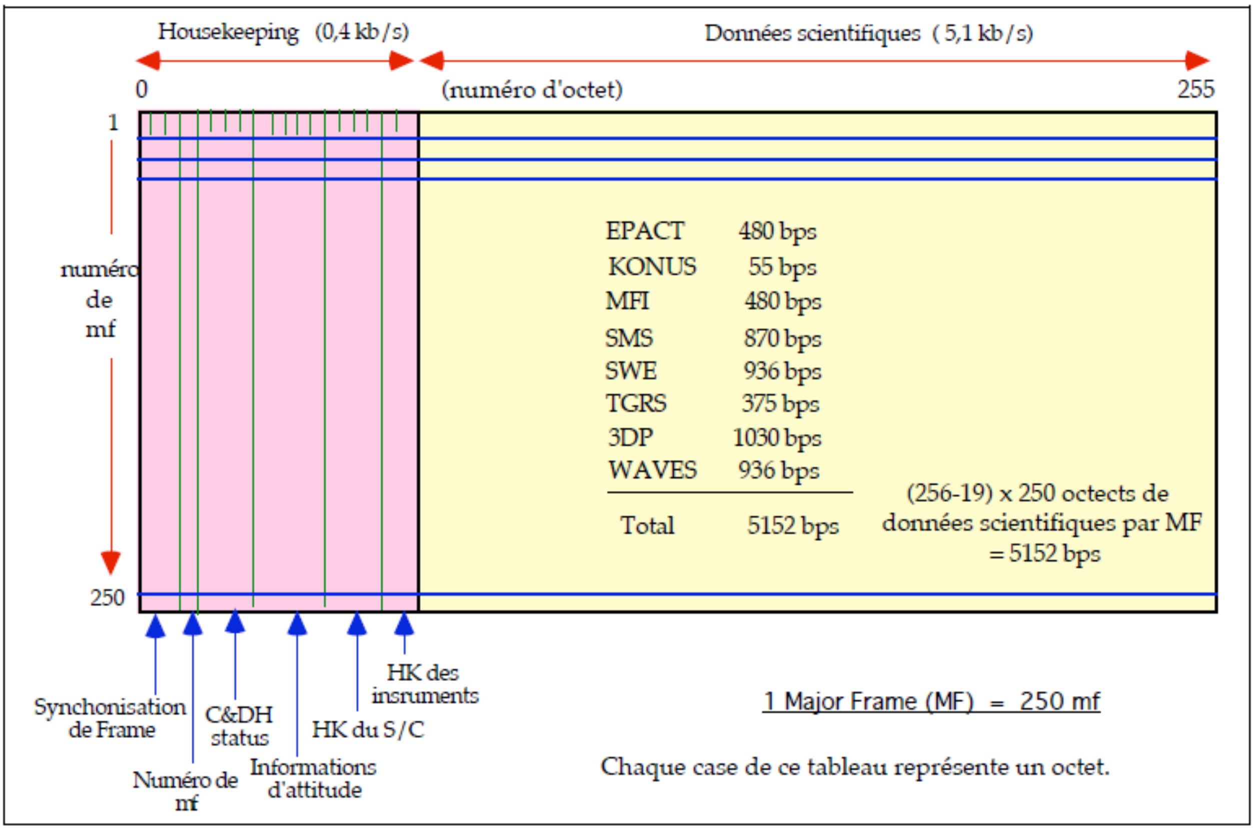


Fig. General structure of a Major Frame (MF) - case of "Science" mode

[11] Usually a measurement cycle is one event. The TNR instrument is an exception in that a TNR event contains several measurement cycles.

2.3.2. Telemetry modes

Science mode: this is the basic configuration for science data acquisition. It is the telemetry mode mainly used during the mission.

Maneuver mode: this mode is used during the various maneuvers and deployments of the satellite, consequent to NASA's remote controls for attitude, velocity, etc... The Waves experiment continues to acquire data during this mode, especially shortly after launch, to follow the antenna extension phase[12]. This format allows the allocation of additional telemetry quota for attitude sensors, thrusters, mast and antenna deployment. This format was designed to provide additional information related to satellite manoeuvres, without losing telemetry space during routine science operations. It maximizes the amount of science telemetry data that can be collected.

Engineering mode: satellite monitoring mode. Used for launch and initial orbit operations or during satellite emergencies.

Contingency mode: double (identical to) the Science format: it allows to manage unforeseen cases.

2.3.3. Telemetry rate

The overall rate of the WIND satellite is:

In LBR (Low Bit Rate), 1 MF in 92 s, that is:

(250 mf per MF) x (256 words per mf) x (8 bits per word) / (92 seconds per MF) = 5565 bps.

This is the nominal mode (TBC) when the probe is at a very large distance (> 60 R_t) from the ground[13].

In HBR (High Bit Rate), the rate doubles, i.e.:

2 x 5565 = 11130 bps.
This is the nominal mode (TBC) when the probe is close (< 60 R_t) to the ground.

For the Waves experiment, there are two modes of telemetry rates:	
A standard rate:	**936.96** bps.
The rate doubles:	**1873,92** bps.

Scientific data :

936.96 bps = (250 mf per MF) x (43.1 words per mf) x (8 bits per word) / 92 (seconds per MF)
= 59250 words / 92 seconds (HK words not included).

[12] QTN spectroscopy is of interest during antenna output: in particular, the influence of antenna length on the QTN spectrum can be studied.

[13] The Flight Operating Team (FOT) decides, based on the signal-to-noise ratio, to switch from HBR to LBR mode.

Data from Housekeeping(HK):

6.52 bps = (75 words per FM) x 8 (bits per word) / 92 (seconds per FM)
= 600 words / 92 seconds

For each experiment the nominal telemetry rate is, for both telemetry rates approximately:

Receiver	Telemetry rate	
	LBR	HBR
RAD1	8%	4%
RAD2	40%	20%
TNR	25%	25%
FFT	25%	45%
TDS	2%	6%
Total	100%	100%

We note that for the RAD1 and RAD2 instruments, the number of bits sent to the telemetry does not change when switching from LBR to HBR mode. On the other hand, it is doubled for the TNR instrument, and greatly increased for the FFT and TDS instruments.

Remarks

- The telemetry rate of one or more instruments can be reduced, if necessary. The telemetry rate of the other instruments can then be increased. If one of the instruments fails, the corresponding telemetry rate is distributed to the other instruments according to priorities.

- The flexibility implemented in the DPU is such that the data rate can be changed (increased) very quickly if the telemetry availability changes.

- We have the following specific "items":

- BIT_RATE_R4: dynamically gives the telemetry rate.
- BIT_PER_MINORFRAME: *documents the telemetry format*.

- The rates shown in the previous table can be interpreted as follows:

- RAD1 instrument: an event consists of 4 packets which require about 3 minutes of computation. Since the duration of an MF is 92 seconds, the DPU will place 4 packets every 2 MF. Since each MF contains 25 packets, this results in an occupancy rate of 4 / (2 x 25) = 8 % in LBR. Since the flow rate of this instrument is the same in HBR, this rate drops to 4% in HBR.

- RAD2 instrument: an event consists of 3 packets in 24 seconds. The DPU will place 3 packets every 7 mf. This results in an occupancy rate of about 43% in LBR. As the flow rate of this instrument is the same in HBR, this rate is divided by two in HBR.

- TNR instrument: 12 spectra in a packet i.e. 12 x 1.472 s = 17.67 s every 5 mf. The DPU will place 1 packet every 5 mf. This results in an occupancy rate of about 20% in LBR. As the flow rate of this instrument is doubled in HBR , this rate remains the same in HBR.

2.4. Access to data

2-4-1 The WIND/Waves software library

2-4-1-1 General

Access to satellite data classically requires the use of a so-called decommutation program, developed in this case jointly by the University of Minnesota (K. Goetz, Jon Kappler) and the GSFC (C. Meetre et al.). Two basic entities are available for a "transparent" access to the data:

- the database: "Wind_dbms".

- the software library of data access procedures: "Wind Library", which allows to retrieve scientific data in Waves packages. These procedures can be called in C, FORTRAN, or IDL languages. They are all prefixed by the string: W_.

From the outside, the user knows only the names of the descriptive data parameters or "items"[14] . The "item" is the basic unit of information that allows the user to query the software library. Through calls to the W_ITEM_** procedures, the user can acquire both the measurements themselves and auxiliary information, such as instrumental mode, frequency, time, etc. These values are accessible to the user only by events, which group a number of measurements, depending on the experiment. The characteristics of the "items" can be found in the directory: WIND_DBMS. The list of items is obtained by typing the general command:

```
query_database
```

or, for a given instrument, for example RAD1: `query_database/RAD1`

Various general information (basic astronomical quantities, characteristics of the Waves instruments, ...) can also be obtained by means of the command: `query_database/global`.

We then obtain:

(extract)

```
BX_LENGTH          Actual length of Bx antenna (meters)
BX_LENGTH_EFF      Effective length of Bx antenna (meters)
BY_LENGTH          Actual length of By antenna (meters)
BY_LENGTH_EFF      Effective length of By antenna (meters)
BZ_LENGTH          Actual length of Bz antenna (meters)
BZ_LENGTH_EFF      Effective length of Bz antenna (meters)
EARTH_TO_SUN_R4    "An AU - mean distance from Earth to Sun (meters)"
EX_LENGTH          Actual length of Ex antenna (meters)
EX_LENGTH_EFF      Effective length of Ex antenna (meters)
EY_LENGTH          Actual length of Ey antenna (meters)
EY_LENGTH_EFF      Effective length of Ey antenna (meters)
EZ_LENGTH          Actual length of Ez antenna (meters)
EZ_LENGTH_EFF      Effective length of Ez antenna (meters)
REARTH_R4          "Mean radius of Earth (meters)"
RMOON_R4           "Mean radius of Moon (meters)"
RSUN_R4            "Mean radius of solar photosphere (meters)"
```

[14] Wherever possible, the various technical terms have been translated into French, but in some rare cases, as here, for better understanding and in view of established habits, we have preferred to retain their English names. The term "item" in English means article.

Under UNIX , the equivalent of the VMS command: `$query_dbms/global/constant,` will be:

```
% qdb -event global -kind constant
```

The following command provides help and syntax definition: `% qdb -h`

2-4-1-2 Meaning of symbols I and N

- When the letter (N) is specified, it means that the software returns the closest value (N earest) to the time of the current event.
- When the letter (I) is found, it is the linearly interpolated value (I nterpolated) between two values available in the data that is provided.

With the sequence:

```
do i = 1, 10
ok = w_event('TNR')
ok = w_item_R8 (ch,'WIND_ORBIT_X(GSE)_R8',pos_x,1,size)
ok = w_item_R8 (ch,'WIND_ORBIT_SCET_R8',time,1,size)
enddo
```

The software library will return orbit values at the times of successive TNR events, i.e. every few seconds. To do this, it will have to interpolate between the available orbit values. For example, in the figure below, the user requests a value for the X position of the probe in the GSE system at the 11h 27 time of the TNR event. The software library returns the interpolated value 93.685.

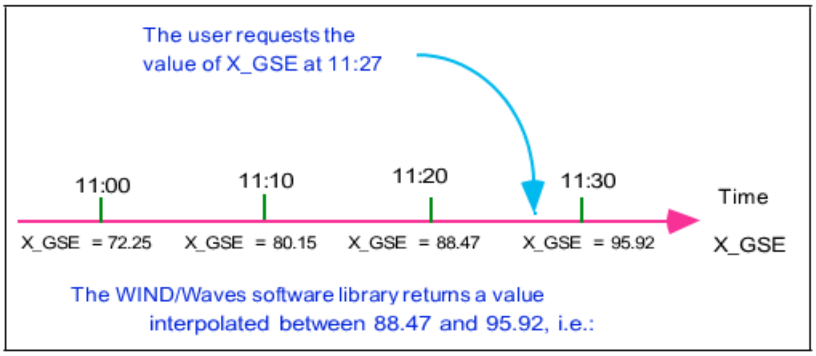


Fig. Interpolation of orbital data

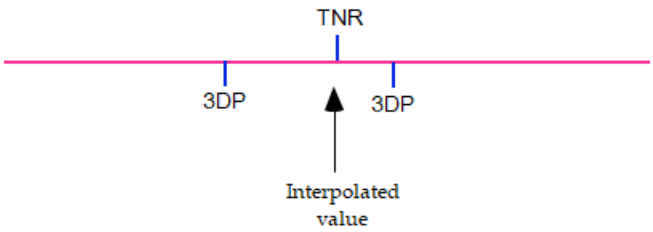
On the other hand, as the item `WIND_MFI_BX(GSE)_R4`, for example, appears with the letter (N):

`WIND_MFI_BX(GSE)_R4` (N) X magnetic field component in GSE (nT)

with the following sequence

```
do i = 1, 10
ok = w_event('TNR')
ok = w_item_R4 (ch,'WIND_MFI_BX(GSE)_R4',mfi,1,size)
enddo
```

The software library will return the magnetic field values at the times of the successive MFI events. Indeed, it has been chosen not to interpolate the scientific data. In the same way, when in a program, the user asks for example for data from the 3DP experiment during the analysis of a TNR event, the WIND/Waves software library proposes the closest value to the TNR event considered, and not the interpolated value.



The level of temporal resolution of the scientific data in CDF format is given in Table ...... at the end of the chapter.

2-4-1-3 Basic procedures

Below are some basic procedures of the WIND/Waves software library, most useful for post-launch data extraction and analysis. The software documentation for the WIND/Waves software library can be found at the file level:

```
WIND_ROOT:[DOC]USER.MANUALandWIND_ROOT :[DOC]DEVELOPER.MANUAL
```

You can find a lot of information not detailed here, among others, a description of each procedure, examples of use, the list of errors returned by the procedures, etc... A complete list and documentation of all procedures is available online in the file WIND_DOC:developers.guide, Appendix E.

Type procedural	Name	Description
Channel	W_CHANNEL_CLOSE	Closes an open channel
	W_CHANNEL_FILEND AME	Gives the name of a file
	W_CHANNEL_OPEN	Open a new channel
	W_CHANNEL_POSITION	Position the pointer in an open channel
Environment	W_MESSAGES_OFF	Disable detailed messages
	W_MESSAGES_ON	Enable detailed messages
Event	W_EVENT	Acquires the new event available for this channel
Item	W_ITEM_CHAR	Returns CHAR ITEM values
	W_ITEM_I4	Returns I*4 ITEM values
	W_ITEM_R4	Returns R*4 ITEM values
	W_ITEM_R8	Returns R*8 ITEM values
	W_ITEM_XLATER	Send item translations
	W_ITEM_FORMAT	Returns a suggested output format specification
Conversion of time	W_UR8_FROM_YDOY	Gives UR8 format from YYYY, DOY and MSEC_of_day
	W_UR8_FROM_YMD	Gives the UR8 format from: YYYY, MM, DD, HH, MM, SS and MSEC

Type procedural	Name	Description
	W_UR8_FROM_YMD_I	Gives UR8 format from: YYYYMMDD, HHMMSS
	W_UR8_FROM_EPOCH	Gives the UR8 format from the Epoch CDF
	W_UR8_TO_STRING	Gives the format DD-MMM-YYYY, HH:MM:SS. mmm
	W_UR8_TO_STRING_FR	Gives the format DD-MMM-YYYY, HH:MM:SS. mmm
	W_UR8_TO_YDOY	Gives the format YYYY, DOY, MSEC_of_day from the time UR8
	W_UR8_TO_YMD	Gives the format YYYY, MM, DD, HH, MM, SS, MSEC from time UR8
	W_UR8_TO_YMD_ID	Gives the format YYYYMMDD, HHMMSS from time UR8
	W_UR8_TO_EPOCH	Gives the CDF epoch from time UR8
	W_UR8_TO_FILENA ME	Delivers a complete CDHF file format specification
Various	W_VERSION	Gives the version number of the WIND/Waves software library.
	W_STATUS	Gives the last return code of W_EVENT

To read directly the values of an "item", we can execute a program written by C. Meetre:

$items<carriage return>

For more information, you can do: $items/help<carriage return>

or:

```
$set def WIND_PROGRAMS
$typ items.doc
```

2-4-2 Programming with the WIND/Waves software library

A program for reading Waves data through the WIND software library typically includes the following steps:

- Opening a zero level file either in batch mode: ok=W_open (ch, filename)

  or in interactive mode: ok = W_open (ch,'offline)

- Positioning at a given time : ok=W_CHANNEL_POSITION (ch, ur8_debut)

- Search for a certain event type (RAD1, RAD2, TNR, TDS, FFT), e.g.:

  ok = W_event(ch, 'RAD1')

- Generally, search for the characteristics of the event, for example, for RAD1/2 instruments, Linear scan, list or fixed frequency mode:

```
ok = W_item_i4(ch, 'EVENT_STATE', mode, 1, ret_size)
```

The `mode` integer will contain 0 (error), 1 (fixed frequency mode), 2 (linear scan mode) or 3 (list mode).

- Search for a particular "item", for example:

```
ok = W_item_i4 (ch, 'S', data_S, 256, length)
```

The `data_S` array will contain 256 values from the sum of the Ex and Ey antennas.

It is prudent to test the return code of the software library procedures. For example, when opening a zero level file in batch mode:

```
ok = W_open (ch, filename)
if (ok.ne.1) stop 'we can't open a telemetry channel
```

The values of the function return codes and their meanings are given in the user manual.

Note:

It is possible to design the extraction of RAD1/2 data taking into account the way the data are arranged, according to the DPU operating algorithm for RAD1/2. In practice, this approach is complex and there is always the risk of not having foreseen all possible cases. It is probably better to extract measurements, times and frequencies. These 3 tables correspond exactly:

Measures (S_..)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Time (S_SCET_R8)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Frequencies	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

When we don't know the size of an array, we can always oversize it on call and use the return size provided by the procedure.

The source code below is a very simple example of a program written in the FORTRAN language, which allows the extraction and recording in a file of data from the RAD1 receiver, from the E_z antenna, in linear scan mode[15]:

```
integer*4 data_z(256)
integer*4 return_code, channel, length real*8time(256)

INCLUDE 'WIND_EXAMPLES:WIND_TM_ROUTINE_DEF.FOR'

return_code = W_channel_open (channel, 'offline')! Open a channel in
interactive mode
```

[15] The user will have taken care beforehand to execute the appropriate command to set up the WIND/Waves software environment, see appendix.

```
open (unit=1,file='FICHIER_RAD1_Z.DAT',status='new')

do i = 1,100
return_code = w_event (channel, 'RAD1')  ! search for the event following
return_code=w_item_i4(channel,'Z',data_z,256,length)  ! extract 256 values  Z
return_code=w_item_r8(channel,'Z_SCET_R8',time,256,length)  ! associated times
print*,'Times associated with data' print*,time
print*,'Antenna data Z, receiver RAD1' print*,data_z
write (1,*) data_z enddo

close(1)
stop
end
```

Remark: as it can be seen in the above example, it is necessary to insert in the programs calling the WIND/Waves software library, the line:

```
INCLUDE 'WIND_EXAMPLES:WIND_TM_ROUTINE_DEF.FOR'
```

The procedures of the WIND/Waves software library used are explained below:

Instruction	Action
`status = W_channel_open(canal,’OFFLINE’)`	Opens a "channel" in interactive
`status = W_event(canal,'RAD1')`	Opens access to the next RAD1 event
`status = W_item_I4(channel,'Z',data_Z,256,length)`	Extracts the Z (integer) data from the current event and places it in the array with the name `donnees_z`.
`status= W_item_R8(channel,'Z_SCET_R8',time,256,length)`	Returns the Z data times in ULYSSE format.

When you want to specify a file name directly, you replace the line in this program:

```
return_code = W_channel_open(channel, 'offline')
```

by:

```
return_code = W_channel_open(channel,'WIND_.....V01')
```

Data can be accessed in two ways:

- in an interactive way: the window like this one appears:

```
X$ run  RAD1_EXTRAIT

 Current Directory is WIND_LZ_ROOT:[WAVES.9412]                        20-
JUN-96
     ____________________________________________________________________
     |   2. [-]                                                          |

     |                                                                   |
     |                                                                   |
     |                                                                   |
     |                                                                   |
     |___________________________________________________________________|
     |    1. WI_LZ_WAV_19941231_V01.DAT                              x
     |    2. WI_LZ_WAV_19941230_V01.DAT                              x
     |    3. WI_LZ_WAV_19941229_V01.DAT                              x
     |    4. WI_LZ_WAV_19941228_V01.DAT                              x
     |    5. WI_LZ_WAV_19941227_V01.DAT                              x
     |    7. WI_LZ_WAV_19941225_V01.DAT                              x
     |    8. WI_LZ_WAV_19941224_V01.DAT                              x
     |    9. WI_LZ_WAV_19941223_V01.DAT                              x
     |    10. WI_LZ_WAV_19941222_V01.DAT
     x
     |    11. WI_LZ_WAV_19941221_V01.DAT
     x
     |    12. WI_LZ_WAV_19941220_V01.DAT
     x
     |                                                                   |
     |___________________________________________________________________
     OPTIONS:  Help  Up  Realtime  LastFile  Prompt  Info  K-ShowLast
VirtualDir
```

In this case, the name of the selected file is retrieved by means of the instruction:

```
W_channel_filename(channel,filename)
```

- or by specifying the file name.

The program presented above is written in IDL language:

```
code_retour    = 0l
canal          = 0l
longueur       = 0l

temps          = dblarr(256)
donnees_z = lonarr(256)

code_retour = W_channel_open (canal, 'offline')

openw,1,'FICHIER_RAD1_Z.DAT'

for j = 1,100 do begin

     code_retour = w_event (canal,'RAD1')
     code_retour = w_item_i4 (canal, 'Z', donnees_z, 256, longueur)
     code_retour = w_item_r8 (canal, 'Z_SCET_R8', temps, 256, longueur)

     print,'Temps associes aux donnees'
     print,temps
     print,'Donnees antenne Z, recepteur RAD1'
     print,donnees_z
     printf,1,donnees_z

endfor

close,1

end
```

2.4.3. Time designation

The WIND software library processes time information in the UR8 format, which is used for the decomposition of ULYSSE/URAP data. This time is given in floating point and in double precision. It indicates the number of days since January 1st, 1982, as well as the fractional part of the day, i.e:

Number of milliseconds elapsed / 86 400 000

There are indeed: 24 x 60 x 60 x 1000 = 86 400 000 milliseconds in 1 day.

Procedures are available to convert this UR8 format to other standard (integer, string) time description formats, and a complementary set of procedures converts standard integer formats to UR8 format.

2.4.4. Files in CDF format

2.4.4.1. Reading and visualizing data

The Common Data Format (CDF) is a file format that contains selected experimental data, processed and reduced to meaningful physical parameters[16] . In the Waves experiment, the key parameters as well as

[16] The CDF is a concept that originated with the National Space Science Data Center (NSSDC). It should be noted that the CSDS (Cluster Science Data System) project is the European counterpart to the American Central Data Handling Facility (CDHF). Bringing together the various national centres and ESA, and designed for the Cluster mission, the CSDS consists of an

the orbit, attitude and spin phase data are available in this format. It is important to note that all ISTP missions adopt this file format definition. To read a file in CDF format, the following five possibilities are available

- use the functions of the NSSDC CDF library. *In FORTRAN.*
- use the CDF functions integrated into the IDL language (from recent versions of this language)[17].
- use access through the WIND/Waves software library ("WIND Library").
- use the KPVT software for data visualization[18] .
- use the "istpadm" tool of the ISDAT[19] software.

The access to the data in the CDF files by means of the WIND/Waves software library is somewhat peculiar, as the latter is basically intended to provide access to the level zero data. This is done as follows:

We open a channel, as if we wanted to access a zero level .DAT file, and we request a CDF "event" (procedure w_event). We then have indirect access to the CDF file of the same day as the .DAT file for which we have opened a channel:

```
          .

          .
st     =     w channel open(ch,                   or             st     =
w channel open(ch,filename.DAT)
```

```
st = w_event(ch,'CDF')
```

An example of a satellite position reading program is given below to illustrate this feature.

The different "items" related to the data in CDF format can be obtained by using the keyboard command:

```
query_database/CDF
```

2.4.4.2. Key parameters of Waves experiments

The key parameters provide information on the other experiments on board the WIND satellite. We

---

elaborate system for producing and distributing the mission's key parameters (PPD: Prime Parameter Data and SPD: Summary Parameter Data) in CDF format to the various space research laboratories.

[17] It should be noted that the CDF functions of the IDL language are the same as the functions of the NSSDC CDF library (TBV).

[18] The KPVT (Key Parameters Visualization Tool) software, written in IDL language and equipped with a graphical interface, allows to visualize the files in CDF format. In the appendix, we present some aspects of this software, available at the CDHF in the directory: SYS$PUBLIC:[TOOLS.KP_PLOT]. To view files in CDF format, one can also develop one's own software environment using the above-mentioned features.

[19] The CDF files of all ISTP components can be read using the ISDAT (Interactive Scientific Data Analysis Tool) software developed by the Swedish Institute for Space Physics (IRFU: Institute for RymdFysik, Uppsala, Sweden). Initially developed for the VICKING mission and now used for the FREJA mission and the EISCAT ground-based observing equipment, it is to be used at DESPA for data analysis of the Cluster and TSS missions.

have the following breakdown:

WIND_KP_ROOT:[WAV]	KP files of the Waves experiment	wave experiment
WIND_KP_ROOT:[MFI]	KP files from the MFI	wave experiment
WIND_KP_ROOT:[SWE]	KP files from the SWE	particles experiment
WIND_KP_ROOT:[3DP]	KP files from the 3DP	particles experiment
WIND_KP_ROOT:[EPACT]	KP files from the EPACT	particles experiment
WIND_KP_ROOT:[SMS]	KP files from the SMS	particles experiment
WIND_KP_ROOT:[KO]	KP files from the KONUS	gamma rays experiment
WIND_KP_ROOT:[TGR]	KP files from the TGRS	gamma rays experiment

At present, the last four directories are empty. Note that the data from the two gamma-ray burst experiments are not used by the wave experiments.

2.4.4.3. Orbit, attitude and spin phase data

The orbit, attitude and spin phase files are in CDF format and can be accessed as described above. They give the position of the probe every 10 minutes. Each daily file therefore contains 6 x 24 = 144 points[20]. There are three types of files: definitive data files, predicted data files, and long term orbit files. Since the latter have a resolution of only one day, when a user requests the position or attitude of the probe at a particular time, the WIND/Waves software library determines it by interpolation[21].

The long-term forecast data do not take into account the satellite thrusts: they do, however, indicate a general trend. The predicted data files are progressively replaced by definitive data files, when available. The nomenclature of the orbit, attitude and spin phase files makes it possible to recognize these three possible types of files (see below). When definitive data files are not yet available, the WIND/Waves software library uses the predicted data files in a transparent way.

`WIND_ORBIT` is a logical name meaning: "`WIND_ORBIT`" = "`WIND_OA_ROOT`:[`ORBIT`]" (`OA`: for Orbit - Attitude). This directory contains the orbit data. Similarly, the directory `WIND_ATTITUDE` for: `WIND_OA_ROOT`:[`ATTITUDE`] contains the attitude data, and the `WIND_SPIN_PHASE` directory for: `WIND_OA_ROOT`:[`SPIN_PHASE`], the "spin phase" data (angle to the sun direction).

The names of the orbit, attitude and spin phase files at DESPA can be viewed as follows:

[20] Some days have missing data.

[21] This is not the case for scientific data in CDF (key parameter) format, which are not interpolated as a matter of principle.

```
$DIR WIND_ORBIT

Directory WIND_OA_ROOT:[ORBIT]

WI_OR_DEF_19941102_V02.CDF;1          WI_OR_DEF_19941103_V02.CDF;1
WI_OR_DEF_19941104_V02.CDF;1          WI_OR_DEF_19941105_V02.CDF;1
WI_OR_DEF_19941106_V01.CDF;1          WI_OR_DEF_19941107_V01.CDF;1

etc...

WI_OR_PRE_19951027_V01.CDF;1          WI_OR_PRE_19951028_V01.CDF;1
WI_OR_PRE_19951029_V01.CDF;1          WI_OR_PRE_19951030_V01.CDF;1
WI_OR_PRE_19951031_V01.CDF;1

Total of 433 files.

X$ DIR WIND_ATTITUDE

Directory WIND_OA_ROOT:[ATTITUDE]

WI_AT_DEF_19941102_V01.CDF;1          WI_AT_DEF_19941103_V01.CDF;1
WI_AT_DEF_19941104_V01.CDF;1          WI_AT_DEF_19941105_V01.CDF;1
WI_AT_DEF_19941106_V01.CDF;1          WI_AT_DEF_19941107_V01.CDF;1

etc...

X$ DIR WIND_SPIN_PHASE

Directory WIND_OA_ROOT:[SPIN_PHASE]

WI_K0_SPHA_19941102_V03.CDF;1         WI_K0_SPHA_19941103_V03.CDF;1
WI_K0_SPHA_19941104_V03.CDF;1         WI_K0_SPHA_19941105_V03.CDF;1
WI_K0_SPHA_19941106_V03.CDF;1         WI_K0_SPHA_19941107_V03.CDF;1

etc...
```

The WIND/Waves software library also provides access to some key parameters of the GEOTAIL (orbit, magnetic field vector) and POLAR (orbital parameters) missions. It is also planned to include data from the CANOPUS ground station, associated with the GGS program. Similarly, the library provides access to the lunar orbit. These files will be obtained in the same way as before:

```
$DIR GEOTAIL_ORBIT

$DIR MOON_ORBIT
```

Of course, the corresponding files need to be repatriated to DESPA or read from CD/ROMS.

2.4.4.4. Orbit data in the software library

The WIND software library provides the following orbital information[22]:

Item name	I/N	Meaning	Adjustment range and/or unit
EARTH_HELIOLAT_R8	I	Terrestrial heliographic latitude	-1.6 à 1.6 radians
EARTH_HELIOLONG_R8	I	Terrestrial heliographic longitude	0 to 6.28 radians
WIND_ATT_DEC(GSE)_R4	N	Declination of WIND in GSE[23]	Radians
WIND_ATT_RA(GSE)_R4	N	Right ascension of the WIND probe in GSE[24]	Radians
WIND_ATT_SCET_R8	N	Time corresponding to the attitude values of the WIND	UR8
WIND_ATT_SPIN_RATE_R4	N	Rotational speed of the WIND[25] probe	Rotations per minute
WIND_ORBIT_HELIOLAT_R8	I	Heliographic Latitude of the WIND probe	-1.6 à 1.6 radians
WIND_ORBIT_HELIOLONG_R8	I	Heliographic longitude of the WIND probe	0 to 6.28 radians
WIND_ORBIT_SCET_R8	I	Time corresponding to the orbital values of the WIND probe	UR8
WIND_ORBIT_VX(GSE)_R8	I	V_X speed of WIND in the GSE system	Km/s
WIND_ORBIT_VY(GSE)_R8	I	V_Y speed ""	Km/s
WIND_ORBIT_VZ(GSE)_R8	I	V_Z speed ""	Km/s
WIND_ORBIT_X(GCI)_R8	I	X position of WIND in GCI coordinates	Km
WIND_ORBIT_X(GSE)_R8	I	" GSE	Km
WIND_ORBIT_X(GSM)_R8	I	" GSM	Km
WIND_ORBIT_Y(GCI)_R8	I	Y position of WIND in GCI coordinates	Km
WIND_ORBIT_Y(GSE)_R8	I	" GSE	Km
WIND_ORBIT_Y(GSM)_R8	I	" GSM	Km
WIND_ORBIT_Z(GCI)_R8	I	Z position of WIND in GCI coordinates	Km
WIND_ORBIT_Z(GSE)_R8	I	" GSE	Km
WIND_ORBIT_Z(GSM)_R8	I	" GSM	Km

Remarks

- This trajectory data is provided as key parameters with a resolution of 10 minutes. They can also be found in the directory (the conformity of this data will be checked): ISTP1:: MISSION_DATA:[SPOF.LTSP].

[22] Table after K. Goetz. We will do: query_database/global/cdf.
[23] obtained from FDF/O&A.
[24] obtained from FDF/O&A.
[25] obtained from FDF/O&A.

- Similar information is also provided for the GEOTAIL and POLAR satellites, as well as the lunar ephemeris. Elements for accessing these data are provided in Chapter 2.

The definitions of right ascension, declination, heliographic latitude and longitude, GSE, GSM and GCI are given in the appendices. (TBW)

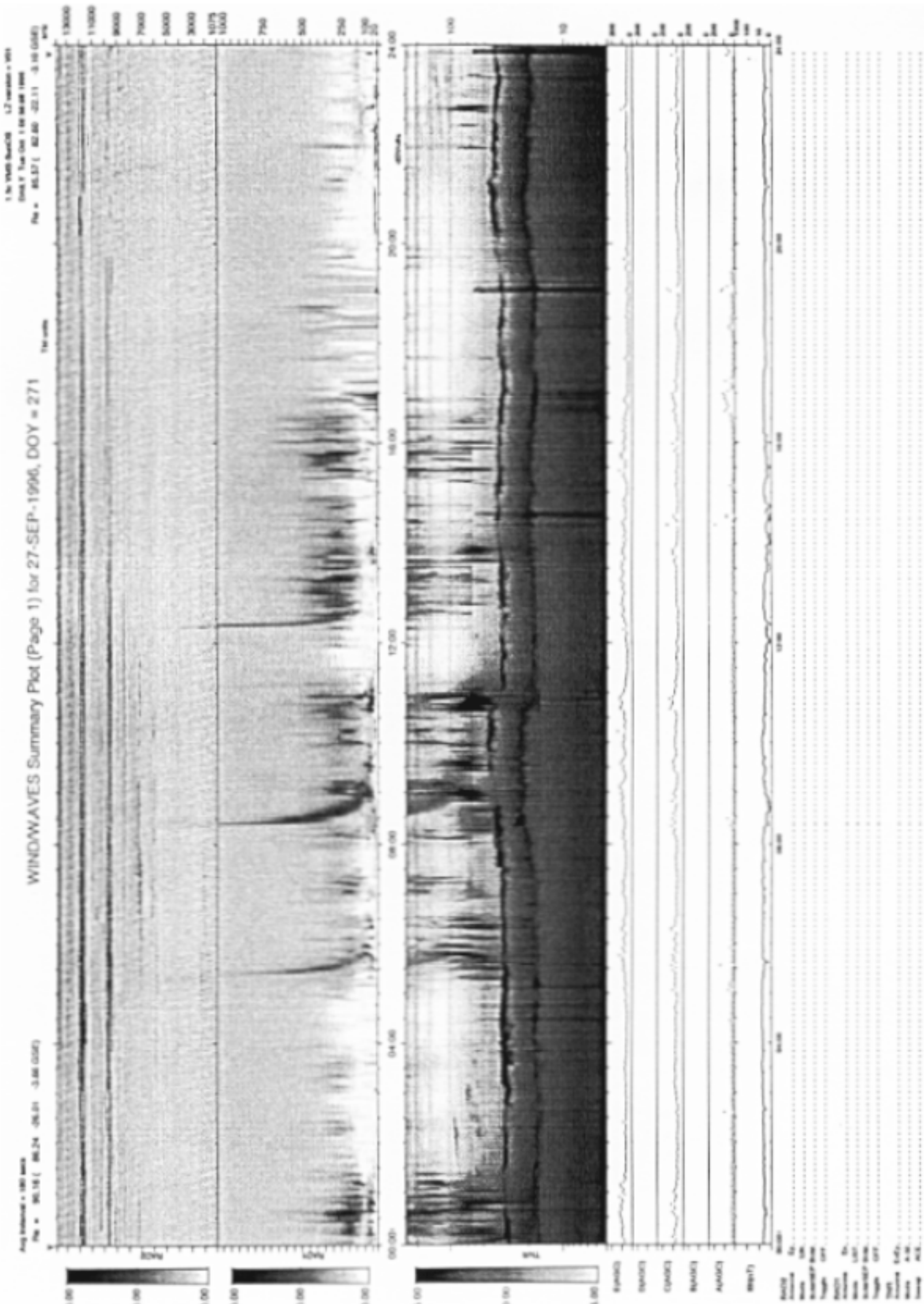
We give below a program in FORTRAN language allowing to know the position of the WIND satellite at a given time. This program illustrates the specific access mode to CDF format data:

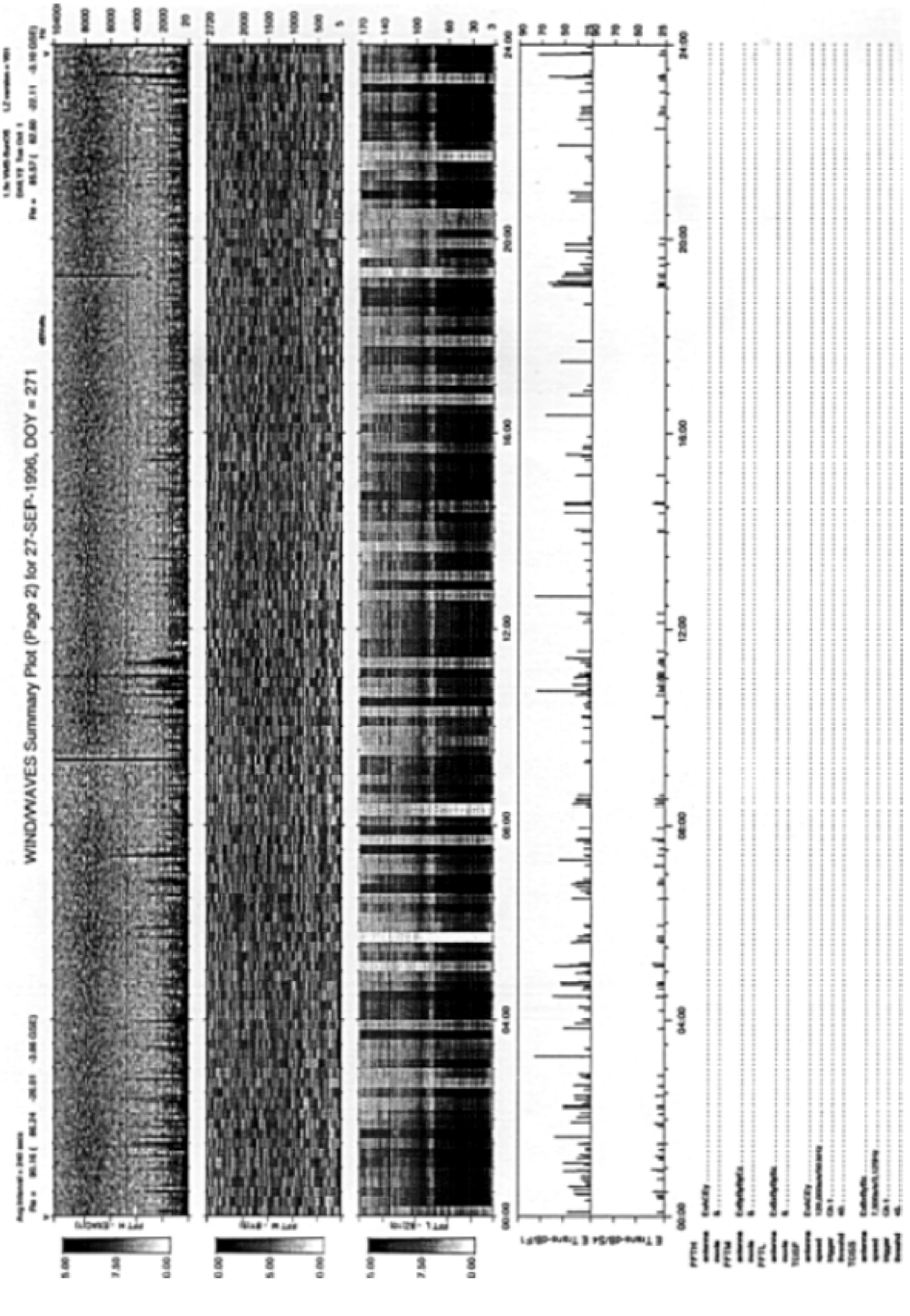
```
      DOUBLE PRECISION    pos_x(144), pos_y(144), pos_z(144), time(144)
      DOUBLE PRECISION    pos_x_RT(144), pos_y_RT(144), pos_z_RT(144)
      INTEGER                   taille,code_retour,canal
      CHARACTER*6         date
      CHARACTER*100       nom_fichier
      CHARACTER*25        temps

      Include 'WIND_EXAMPLES:WIND_TM_ROUTINE_DEF.FOR'

c                          Jour demande  -  choix GSE / GSM

      write(5,100)
100   format(x,'entrez la date entre cotes sous la forme ''aammjj'' : ',$)
      read(5,*)date
      nom_fichier='WIND_LZ_ROOT:[WAVES.'//date(1:4)//']WI_LZ_WAV_19'//date//'_V*.DAT'
      write(5,200)
200   format(x,'GSE [1] ou GSM [2] ? ',$)
      read(5,*)rep_coord
c                          Lecture des données

      code_retour = w_channel_open(canal,nom_fichier)          ! Ouverture d'un canal
      code_retour = w_event(canal,'CDF')                       ! Recherche de l'événement CDF suivant

      code_retour = w_item_R8 (canal,'WIND_ORBIT_SCET_R8',time,144,taille)

      if(rep_coord .eq. 1) then
      code_retour = w_item_R8 (canal,'WIND_ORBIT_X(GSE)_R8',pos_x,144,taille)  ! 144 valeurs de X_GSE
      code_retour = w_item_R8 (canal,'WIND_ORBIT_Y(GSE)_R8',pos_y,144,taille)  ! 144 valeurs de Y_GSE
      code_retour = w_item_R8 (canal,'WIND_ORBIT_Z(GSE)_R8',pos_z,144,taille)  ! 144 valeurs de Z_GSE
      else
      code_retour = w_item_R8 (canal,'WIND_ORBIT_X(GSM)_R8',pos_x,144,taille)  ! 144 valeurs de X_GSM
      code_retour = w_item_R8 (canal,'WIND_ORBIT_Y(GSM)_R8',pos_y,144,taille)  ! 144 valeurs de Y_GSM
      code_retour = w_item_R8 (canal,'WIND_ORBIT_Z(GSM)_R8',pos_z,144,taille)  ! 144 valeurs de Z_GSM
      endif

c                          Affichage

      code_retour = w_item_R4 (canal,'REARTH_R4',rt,1,taille)             ! valeur du rayon terrestre
(m)
      Rt = Rt/ 1000.                                                       ! Rt en km

      write (5,300)
300   format(/,37X,'RAY. TER. (X)',3X,'RAY. TER. (Y)',2X,'RAY. TER. (Z)')

      do i=1,144
      pos_x_RT(i) = pos_x(i) / Rt                                  ! Conversion en rayons terrestres
      pos_y_RT(i) = pos_y(i) / Rt
      pos_z_RT(i) = pos_z(i) / Rt
      code_retour = w_ur8_to_string_fr(time(i),temps)            ! Temps en une chaine de caractères lisibles
      write(5,400)temps,pos_x_RT(i),pos_y_RT(i),pos_z_RT(i)
400   format(/,x,a,x,'position',3(F13.5,X))
      enddo

      code_retour = w_channel_close(canal)
      stop
      end
```

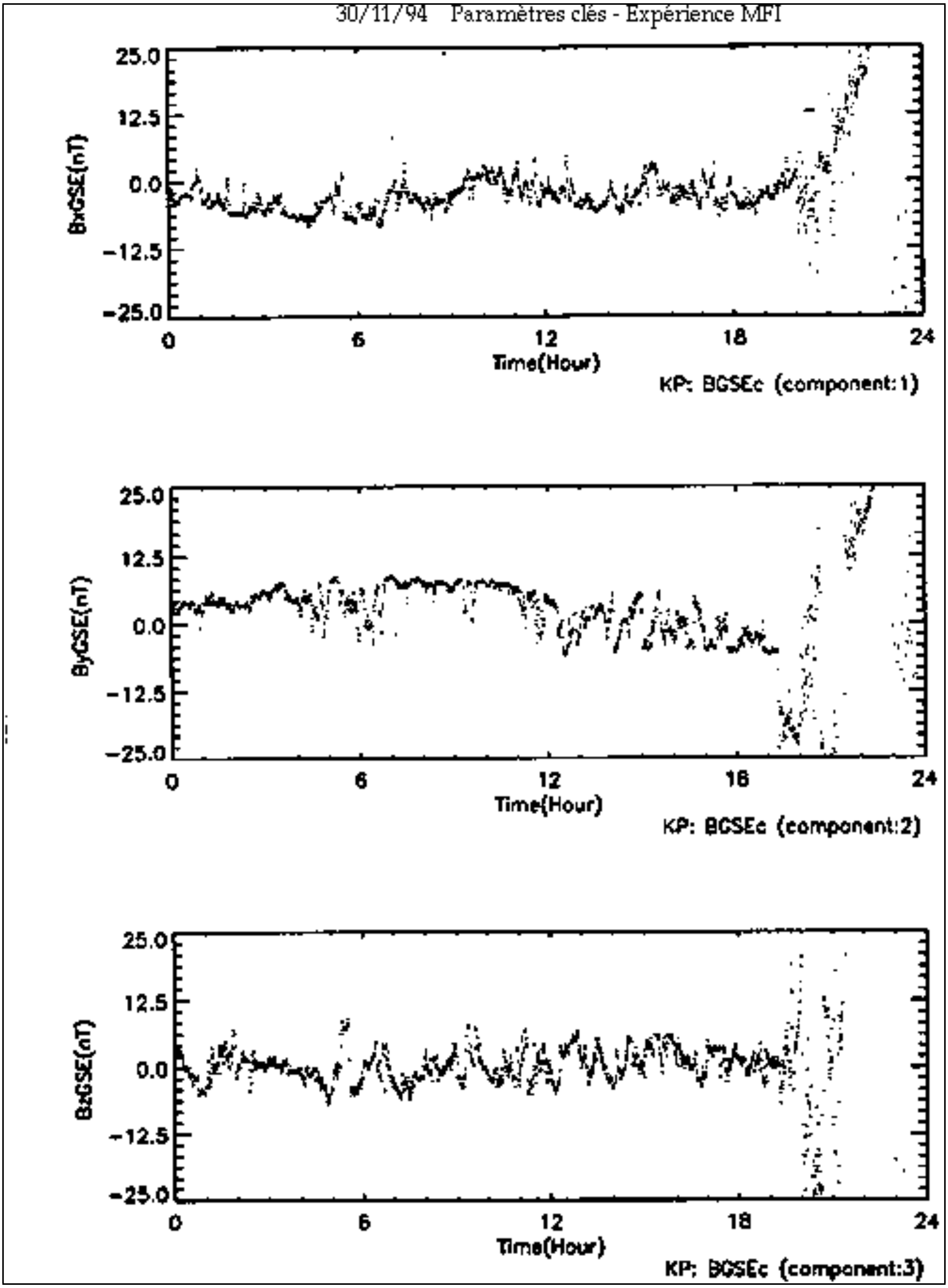
EXPERIMENT	KEY PARAMETERS	TEMPORAL RESOLUTION
MFI	$\lvert\langle B\rangle\rvert$, $\langle\lvert B\rvert\rangle$, RMS, Num. pts. in avg., $(Bx, By, Bz, \phi , \lambda)_{GSM}$, $(Bx, By, Bz\ \varphi , \lambda)_{GSE}$ $(X,Y,Z)_{GSE}$,$(X,Y,Z)_{GSM}$, R	46 or 92 s[26]
WAVES	Ne (electron density), Peak, ave. for **E**, **B** per freq. decade	2 min.
SWE	Bulk velocity: $(Vx, Vy, Vz)_{GSE}$, $(Vx, Vy, Vz)_{GSM}$ $(V, V_{long}, V_{lat})_{GSE}$, proton density, 100 * (alpha part. density/proton density) Most probable proton thermal speed Delta time (1/2 length of spectra) $(X,Y,Z)_{GSE}$, $(X,Y,Z)_{GSM}$, R	at least every 2 mn
3DP	e flux: 7 energies (.1 - 225 keV) ion flux: 7 energies (.07 - 400 keV) N_e, N_i, V_e, V_i, T_e, T_i; e heat flux along **B**, $V_{satellite}$ (GSE), $(X,Y,Z)_{GSE}$	46 or 92 s[26]
EPACT	STEP fluxes: He3(80 - 160 keV/n), He5(320 – 640 keV/n), CNO3 (80 - 160 keV/n), CNO5 (320 – 640 keV/n), Fe3 (80 - 160 keV/n), Fe6(320 – 640 keV/n) LEMT fluxes: He (3.2 - 6.2 keV/n), O(3.2 - 6.2 keV/n), Fe3 (3.2 - 6.2 keV/n) APE-A fluxes: Electrons (0.2-2 MeV/n) Protons (4.6-6.6 keV/n) Protons (6.6 - 25 keV/n) , He (4.6-6.6 keV/n), He (6.6 - 25 MeV/n) APE-B: Electrons (1-10 MeV/n) Protons (19-28 MeV/n) Protons (28 - 72 MeV/n) , He (19-28 MeV/n) He (28- 72 MeV/n)	46 or 92 s[26]
SMS	FLUXED PARTICLES Differential intensity (10^{-6}-10^{5} part/cm2-sec-sr-keV/e) SOLAR WIND PARAMETERS Solar wind Speed: H^+ (150-2370 km/sec) F_e^{+10} (60-100 km/sec) Solar wind Density (10^{-6}-10^{2} cm^{-3})	20 minutes 3.0 minutes 3.0 minutes 3.0 minutes
TGRS	Major Frame Number, Instrument Mode, Fast Rate Counter, Major Frame Accumulation, Average	5.0 minutes

[26] The time resolution increases from 46 seconds (when the satellite is less than 60 R_e) to 92 seconds (when the radial distance exceeds 60 R_e), due to the change in telemetry rate. From Space Science Reviews.

KONUS	—	—




WIND/WAVES Summary Plot (Page 2) for 27-SEP-1996, DOY = 271


30/11/94 Paramètres clés - Expérience MFI
BxGSE(nT)
Time(Hour)
KP: BGSEc (component:1)
ByGSE(nT)
Time(Hour)
KP: BGSEc (component:2)
BzGSE(nT)
Time(Hour)
KP: BGSEc (component:3)

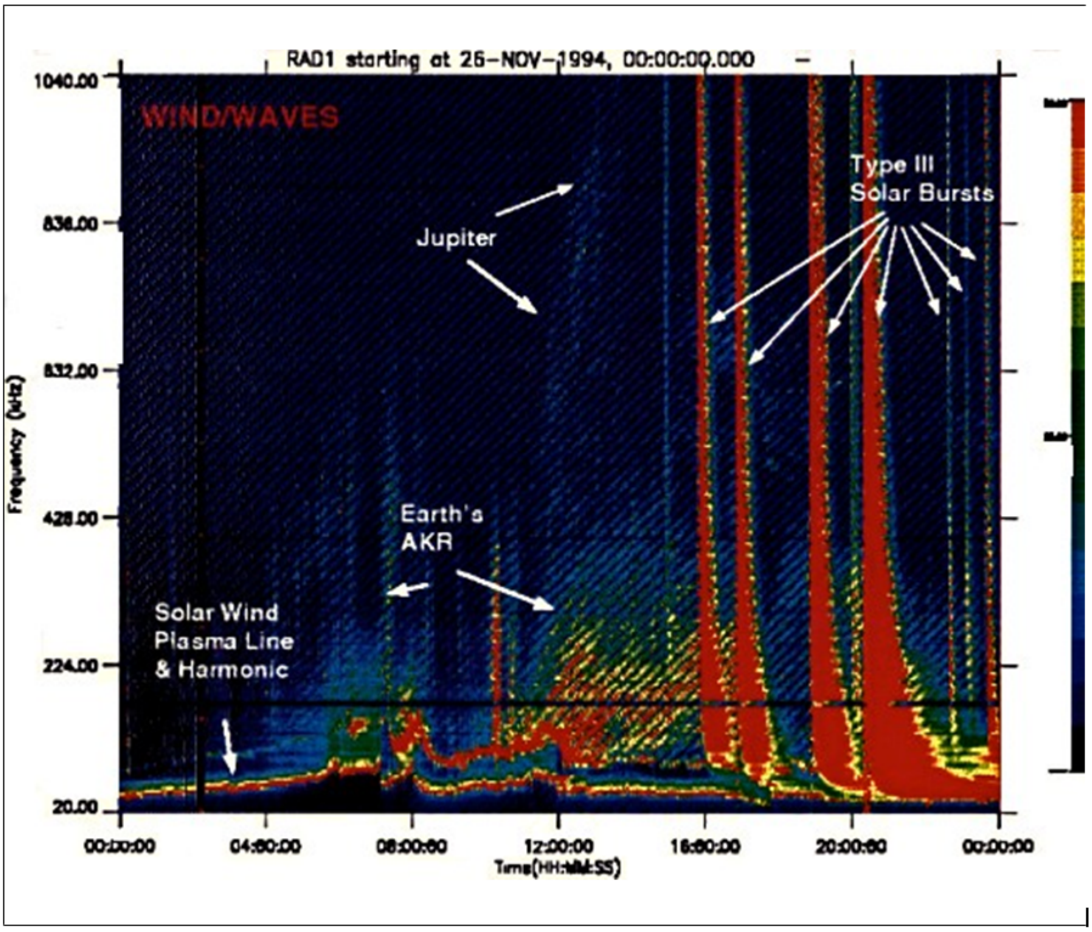
2.4.5. Dynamic spectra of experiments

Several software programs written by Claude Perche allow the plotting of daily dynamic color spectra for RAD1, RAD2 (TBC) and TNR receivers. Such spectrograms are also obtained at the GSFC and the University of Minnesota. These plots, also called "quicklooks", provide a synoptic view of the data over a period of several hours to a day.

They allow, among other things, to locate the plasma line at f_p or even at $2\,f_p$, solar outbursts (most often type III outbursts), planetary emissions (most often AKRs), possible Langmuir wave outbursts, to observe stationary or interplanetary shock crossings, etc...

Examples of such spectrograms are given below.

<u>Example of dynamic spectrum RAD1</u> (1 p)



<u>Example of dynamic spectrum RAD2</u> (1 p)

<u>Example of a dynamic TNR spectrum</u> (C. Perche) (1 p)