SURVEY OF ELF AND VLF EXPERIMENTS IN THE MAGNETOSPHERE

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Paper published in ESA Proceedings in February 2000:
Proceedings of the Cluster II Workshop on Multiscale/Multipoint Plasma Measurements,
London, 22-24 September 1999, ESA SP-449, 307-310, 2000.

ABSTRACT

Global maps of the spatial and frequency distributions of ELF, VLF, and HF waves in the magnetosphere are needed to evaluate quantitatively the sources and losses of energetic particles trapped in the geomagnetic field. The first step is to identify all magnetospheric missions that carried instrumentation to study the electromagnetic environment of the Earth; the second step is to determine the types and the characteristics of the waves observed in space during the past three decades. The next step is to find out where the mission data have been stored and archived and to determine if they are accessible and usable. The status of this survey is reported here.

1. INTRODUCTION

Comprehensive maps of the distribution of VLF, ELF and HF waves in the magnetosphere are lacking. Therefore we envisaged undertaking a survey of the spatial and frequency distributions of magnetospheric waves. We decided to create a database/catalogue that allows:

1. To identify the past and current satellites that have made or are making wave measurements in the magnetosphere;
2. To provide information about wave experiments aboard satellites, i.e. antennas and magnetometers;
3. To supply bibliography about the data sets;
4. To inform about the availability and the location of these data sets;
5. To promote their access and use.

This comprehensive survey should be informative and useful for scientists interested in the study of electromagnetic waves in the magnetosphere; indeed it gives for this subset of magnetospheric satellites the:

1. Orbital elements;
2. Addresses of PI or of Co-I responsible of the wave experiments;
3. Bibliographical references regarding the wave instruments;
4. Bibliographical references of articles using these wave data to investigate the magnetosphere;
5. Regions of the magnetosphere where data have been collected and where they are missing;
6. Frequency ranges for which there are no data available;
7. Online information about availability of the wave data and where to place a request to the PI.

The ultimate aim of this survey is to promote an international effort with the final scientific objective to develop comprehensive three-dimensional empirical models of electromagnetic wave parameters. It means, to build global maps of the spatial and frequency distributions of magnetospheric ELF and VLF waves.

2. SOURCES AND METHOD TO CREATE THIS SURVEY

The comprehensive catalogue or table described below contains all missions/satellites in the terrestrial magnetosphere that were or are equipped with radio antennas and/or fluxgate magnetometers. For each experiment and each mission, the entries have been grouped in 4 categories:

1. Satellite information;
2. Orbital information;
3. Experiment information;
4. Data information.

The sources of the entries are:

1. The NSSDC web site (http://nssdc.gsfc.nasa.gov/) the web sites that hold information about spacecrafts, e.g. the Satellite Encyclopedia Online (http://www.tbs-satellite.com/tse/online/index.shtml) the Mission and Spacecraft Library (http://msl.jpl.nasa.gov/search/ephemeris.html) or the Spacecraft Alphabetical Index (http://www.rocketry.com/mwade/craft/spaindex.htm); and the web sites of international space agencies (ESA, NASA, ISAS and IKI);
2. Review articles about wave experiments in the magnetosphere;
3. The catalogue of satellites available at the Belgian Institute for Space Aeronomy, Brussels (courtesy, J. Vercheval);
4. NASA catalogues;
5. E-mail exchanges with many scientists from the international space community, PI or Co-I of these experiments. It is from these key sources that we obtained the most specific and detailed information about the instruments and the availability of the data sets.

Welcome to SEVEM

Survey of ELF and VLF Experiments in the Magnetosphere

List of All Satellites

Select a satellite in the list below:

A-Es	Et-Go	Go-Im	In-M	N-Z
			INJUN 1	Oersted
Alouette 1	EXOS-A	GOES 6	INJUN 3	OGO 1
Alouette 2	EXOS-B	GOES 7	INJUN 5	OGO 2
AMPTE / CCE	EXOS-D	GOES 8	Interball Auroral	OGO 3
AMPTE / IRM	Explorer 6	GOES 9	Interball Tail	OGO 4
AMPTE / UKS	Explorer 12	GOES 10	Interball S2-X	OGO 5
Astrid 2	Explorer 14	Hawkeye 1	Interball S2-A	OGO 6
ATS 1	Explorer 26	HEOS 1	Intercosmos 14	Polar
ATS 5	Explorer 45	HEOS 2	Intercosmos 22	Prognoz 6
ATS 6	FAST	IMP-A	Intercosmos 24	Prognoz 7
Aureol 3	FR 1	IMP-B	Intercosmos 25	Prognoz 8
Azur	Freja	IMP-C	ISEE 1	Prognoz 9
CRRES	Geotail	IMP-D	ISEE 2	Prognoz 10
Dynamics Explorer 1	GOES 1	IMP-F	ISEE 3	SCATHA
Dynamics Explorer 2	GOES 2	IMP-G	ISIS 1	SMS-1
Equator-S	GOES 3	IMP-H	ISIS 2	SMS-2
ESA-GEOS 1	GOES 4	IMP-I	MAGION 2	Viking
ESA-GEOS 2	GOES 5	IMP-J	MAGION 3	Wind

Figure 1: URL page showing the list of all magnetospheric satellites described in this survey: i.e. carrying radio antennae or/and fluxgate magnetometers.

3. DESCRIPTION OF THE WEB SITE

The web site home page for our survey is at http://www.magnet.oma.be/sevem/. A search engine is provided to select the relevant missions according to frequency ranges or periods of observation. Links are available to the page of each missions/satellite. Other links point to pages with information on each wave experiment of each satellite. Figure 2 illustrates this page for Freja.
There are also links to indexed bibliographical references (e.g. the reference E28.3) reported on each satellite page. An example is shown in Figure 3.

In order to display the frequency ranges of wave data that are available or missing, there is a click button opening a window displaying the frequency ranges of each individual instrument. An example is shown in Figure 4 for the electric field experiments. Another plot opens a window displaying the period of time over which data sets have been collected.

There is also the possibility to display two or three-dimensional plots showing the trajectories of the satellites in different coordinates systems (e.g. GSE or B.L.). Figure 5 displays the first twenty orbits of ten satellites (AMPTE-CCE, AMPTE-UKS, CRRES, FAST, Dynamic Explorer 1, EXOS-D, GOES-8, Interball-Tail, Polar and Viking) in the GSE reference system. It shows which regions of the magnetosphere were visited by the satellites.

Name of the satellite	Freja
Other name(s)	22161
COSPAR designation	92-064A
Project(s) Manager(s) of the satellite	Sven Grahn
Institute of the project(s) manager(s)	SSC
Country or Space Agency	SWE
Launch date (dd-mm-yyyy)	06-10-1992
Termination date (dd-mm-yyyy)	14-10-1996
Lifetime of the satellite (month)	48
Type of the orbits	LEO
(Initial) Perigee (km)	601
(Initial) Apogee (km / Re)	1756 / 0.3
Orbital period (min / hour)	109 / 1.8
Spin rate (rpm)	10
Eccentricity	0.08
Inclination (°)	63
Observed regions	Magnetosphere (oval auroral)
Observed waves	Alfven waves, cyclotron waves, multi-ion resonance, ion sound waves, ion acoustic waves.
Name of the experiment	Plasma Wave Experiment (WAVE)
PI of the experiment or contact person	Bengt Holback
Institute of the PI or of the contact person (country)	IRF-U (SWE)
E-mail of the PI or of the contact person	Bengt.Holback@irfu.se
Type of experiment	Three pairs of 6 cm diameter spherical probes (P1-P6) were mounted at the end of 15 or 7.5 meter wire booms and a tri-axial search coil magnetometer, with one coil parallel to spin axis and the remaining in the spin plane (i.e., one radial and another tangential in the spin plane)
References about the experiment	The Freja wave and plasma density experiment (E28.3)

WEB site (other than NSSDC)	http://sd-www.jhuapl.edu/Freja/
Start experiment operation (dd-mm-yyyy)	06-10-1992
End experiment operation (dd-mm-yyyy)	20-06-1995
Lifetime of the experiment (month)	32
Number of modes of operation	2 (1200 bps/s and 524 kbps/s)
Highest mode of operation	524 kbps/s
Preliminary results	Observation of kinetic Alfven waves by the Freja spacecraft (R28.3)
Measured data (k, w, Bo, E(t), B(t), polarisation, Vphase, ...)	Electric and magnetic fields
Frequency range	E : 0.1 - 4 MHz 0.1 - 600 mV/m B : 0.03 - 16 kHz 1.10-5 - 1.10-1 $nT.Hz^{-1/2}$
Sensitivity	?????
Time resolution	15 s
Sampling rate	E : 8 Msamples/s B : 32000 samples/s
Data formats and supports	Books
Where are the data	Freja Summary Plots (SWE)
References about the data	
High-resolution data (support, place, contact)	Bengt Holback Bengt.Holback@irfu.se

Figure 2: Example of information given for one satellite (Freja)

Code-reference	E28.3
First author	B. Holback
Title	The Freja wave and plasma density experiment
Other authors	S. E. Jansson, L. Ahlen, G. Lundgren, L. Lyngdahl, S. Powell and A. Meyer
Editor / Journal / Book / Place of publication	Space Sciences Review
Volume	70, N3-4
Pages	577-592
Year	1994

Figure 3: Bibliographical references related to the Freja satellite

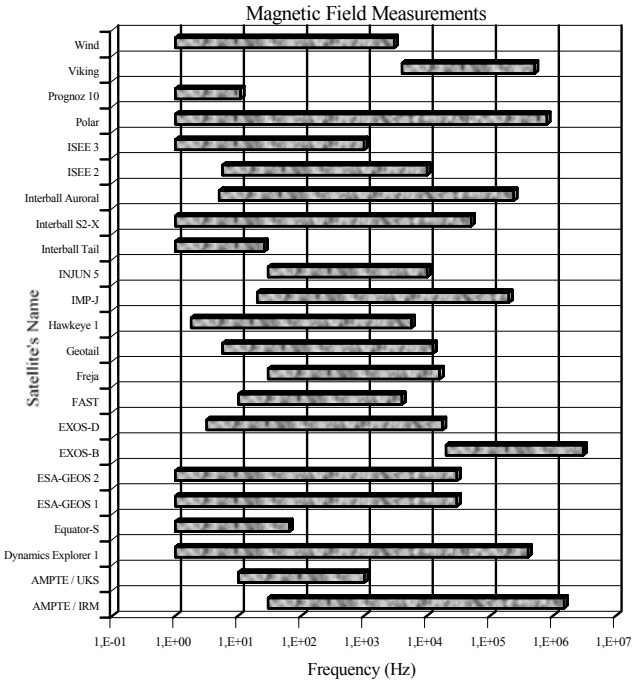

Figure 4: Frequency ranges for which magnetic field observations have been collected for some satellites of the database.

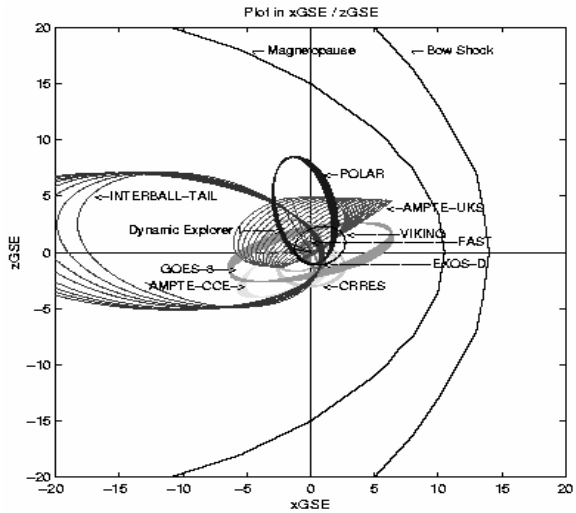

Figure 5: Projection in the (X_{GSE}, Z_{GSE}) plane of the first twenty orbits of ten satellites listed in this catalogue.

4. CONCLUSION

Wave data sets from magnetometers and radio antennas collected for several decades in the magnetosphere onboard satellites have been identified and catalogued. Our catalogue, available on the Web, identifies the missions/satellites, whose data can be analyzed in order to build a database of the electromagnetic VLF and ELF environment for the terrestrial magnetosphere.

This database should contribute to promote the development of empirical models for the three-dimensional distribution of wave parameters (amplitudes, wave vectors, polarization, wave frequency, …) and global maps of the spatial and frequency distributions of ELF, VLF and possibly ULF and HF waves in the magnetosphere. Such maps are of direct interest for a comprehensive evaluation of the sources and losses of energetic particles trapped in the Van Allen radiation belts due to resonant wave particle interactions. These maps should complement standard radiation belt models (such as the AE-8 and AP-8 empirical models mapping the flux of radiation belt electrons and protons) or more recent empirical models of the Earth's environment, currently accessible at SPENVIS: the SPace ENVironment Information System at http://www.spenvis.oma.be/spenvis/. The resulting final validated models will be made to the community through SPENVIS. The international modeling effort will be coordinated by VERSIM (VLF/ELF Remote Sensing of Ionospheres and Magnetospheres at http://www.nerc-bas.ac.uk/public/uasd/versim.html).

From our survey it results that for the time being, 25 satellites measured electric fields and about 35 satellites measured magnetic fields whose data should be currently accessible. We conclude that only 40 satellites are usable, but neither in all frequency ranges nor in all regions of the magnetosphere.
This indicates the need for additional satellites with experiments devoted to study the electromagnetic environment of outer space. Future missions like CLUSTER II or DEMETER should help to fill up these gaps.

5. ADDITIONAL REMARKS

The Commission H (Plasma Waves) of URSI (Union Radio Science International) supports this modeling effort to survey and map the ELF and VLF wave environment. It has voted at the URSI 1999 General Assembly, in Toronto, a Recommendation along these lines. The full text of this recommendation is available at: http://www.magnet.oma.be/sevem/URSI-Recommendation.html.
This present article is also available on the Web page of the SEVEM (Survey of ELF and VLF Experiments in the Magnetosphere) project at: http://www.magnet.oma.be/sevem/article-ClusterII.html.

6. AKNOWLEDGEMENTS

The number of scientists who kindly contributes to these inputs is too large to cite all their names here. But we wish to thank them all collectively for their cooperation and help to create the SEVEM (Survey of ELF and VLF Experiments in the Magnetosphere) catalogue.