Using space mission data (DEMETER)

M. Parrot[1]

[1] *LPC2E, University of Orléans, CNRS, Orléans, France*

DEMETER was a low earth orbiting satellite in operation between 2004 and 2010. Its main scientific objectives were the studies of the ionospheric perturbations as function of the seismic activity and as function of the man-made activities. Its payload consists of experiments to measure electromagnetic waves and plasma densities. Therefore DEMETER was able to record a lot of events related to the thunderstorm activity. The training lesson about DEMETER will start by a short presentation of the satellite, its operations, its experiments and the corresponding data. Then it will be possible to perform analysis of data recorded during interesting events at the time of thunderstorm activity. This will be done with a specific software named SWAN specially developed by LPC2E to analyze electromagnetic waves.

1. Introduction

During this training lesson specific events recorded by the low altitude satellite DEMETER during thunderstorm activity will be studied with a software named SWAN.

2. The satellite DEMETER

DEMETER was a 3-axis stabilized Earth-pointing spacecraft launched on June 29, 2004 into a low altitude (~710 km) polar and circular orbit that was subsequently lowered to 650 km till the end of the mission in December 2010 [1]. The orbit is nearly sun-synchronous with an ascending node at ~22.30 LT in the night sector and a descending node at ~10.30 LT during day-time. The payload was nearly continuously operated at invariant latitudes below 65° but dedicated operations were also programmed at higher latitudes when the satellite was flying over ground-based facilities such as EISCAT or HAARP. Data studied in this lesson were acquired by the Electric Field Instrument (ICE) which measures electric components of plasma waves in the frequency range from DC to 3.25 MHz. The Very Low Frequency (VLF) range of ICE extends from 70 Hz to 20 kHz. There are two scientific modes, survey and burst, the latter being mainly activated when the satellite is above active seismic regions or for specific purposes. In both modes power spectra of one electric component were calculated onboard with a time resolution of 2.048 s and a frequency resolution of 19.53 Hz. In the burst mode waveforms of one electric component with a sampling frequency of 40 kHz were downloaded, which allows spectra with a better time and frequency resolution than in survey mode. In the burst mode it is also possible to achieve a wave propagation analysis using the six components of the wave field up to 1.25 kHz.

A detailed description of ICE can be found in [2]. All events to be studied in this lesson have been recorded during the burst mode of the experiment.

3. SWAN

SWAN (Software for Waveform ANalysis) is a fully interactive software designed for the visualization and analysis of scientific and engineering data. The main objective is to facilitate the satellite data processing providing with a package of analysis tools. The data processing tools can be classified according to the type of analysis:

(i) Pre-processing;

Basic data pre-processing can be done with the data customizer tool. Data selection and cleaning are available. IDL commands and user programs can be executed over the data set.

(ii) Data viewer;

The more basic function corresponds to a quick display of the signal waveform.

(iii) Data characteristics;

The characteristics of the signal are determined after tests on probability distribution, stationarity, normality and moments.

(iv) Classical spectral analysis;

The "classical" spectral analysis of a time signal contains the filtering, the estimations of autocovariance, autospectrum. When at least two different input signals are loaded, the cross-covariance and the cross-spectrum can be estimated. For large sample data inputs, auto and cross spectrograms are computed.

(v) Higher order spectral analysis;

The higher order spectral analysis consists in the analysis of the higher moments, bispectrum (order 3) and trispectrum (order 4) and the estimation of mutual information and derivatives.

(vi) Wavelet analysis;

Auto and cross wavelet analysis (Morlet wavelet) are available with derivative functions as wavelet “spectrogram” (amplitude and phase) or integrated spectrum; bispectrum estimation can also be calculated from wavelet coefficients.

(vii) Wave field characteristics;

When at least three components of the analyzed wave field are available simultaneously, the propagation and polarization characteristics can be estimated.

SWAN's primary task is to provide researchers in geophysics with a set of basic signal processing tools and thus to save them a programmation time of these common functions.

Another important task is to simplify the plotting and display of data coming from space experiments. Finally, SWAN permits to make a first high level data analysis with display facilities. The only condition is that the input data are discrete time-history signals as waveforms.

The reference manuals, User’s Guide [3] and Analysis Tools [4], are meant to give a comprehensive picture of what the SWAN software does, and how it does it.

3. The events

The events to be studied concern whistlers [6, 9], proton whistlers [5, 8], multi-hop whistlers, pulses in HF [7], and data recorded at the time of sprites [10].

4. References

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