Asymmetric V shaped streaks recorded on board DEMETER above powerful thunderstorms

***F. El-Lemdani Mazouz*[1], *H. De Feraudy*[2], *J.L. Pinçon* [3] *and M. Parrot*[4]**

[1] Laboratoire ATmosphère Milieux Observations Spatiales (LATMOS), 11 boulevard d'Alembert, 78280 Guyancourt, France, email : farida.mazouz@latmos.ipsl.fr.

[2] As (1) above, but Email : herve.deferaudy@latmos.ipsl.fr

[3] Laboratoire de Physique et de Chimie de l'Environnement et de l'Espace, 3A Avenue de la Recherche Scientifique, 45071 Orléans cedex 2, France,email : jlpincon@cnrs-orleans.fr

[4] As (3) above, but Email : mparrot@cnrs-orleans.fr

Abstract

Both symmetric and asymmetric forms of V-shaped streaks observed on board DEMETER satellite are reported. . They are associated with intense and numerous 0+ whistlers generated above high active thunderstorms regions. To understand the origin of the different spectral forms, a systematic survey is performed over 5 years of VLF-data. Asymmetric events are more frequently observed for high latitude regions. The importance of the magnetic field orientation on the spectral form observed is pointed out and confirmed by: - A propagation model based on cold plasma properties. - An event study where positions of the lightnings strokes were precisely known

1. Introduction

DEMETER is a French micro satellite designed to study ionospheric perturbations related to seismic and man-made activity. Its payload consists of wave and particle analyzers [*Cussac et al.*, 2006]. The major part of electromagnetic (EM) waves recorded by DEMETER in the ELF-VLF frequency range consists of whistlers observed at low and mid latitudes during nighttime [*Parrot et al.*, 2008a]. The relationship between whistlers and the causative thunderstorm activity is the subject of active research studies The VLF-ULF EM waves generated by lightning in the atmosphere and propagating in the Earth-ionosphere waveguide are known as atmospheric waves [*Heliwell*, 1965]. A part of these waves called 0+ whistlers can cross the ionospheric boundary [*Smith and Angeramy* 1968]. The present work relies on V-shaped events associated with intense 0+ emissions and related to very active thunderstorms. These V-shaped events were first reported and explored by *Parrot et al.* [2008b]. They are the reflect of the mapping to satellite altitude of frequency dependant position of mode interference nulls and crests within the Earth-ionosphere wave guide.. A careful examination of the V-shaped events observed on board DEMETER shows that they are distributed among 3 distinct classes: V-shaped symmetric, V-shaped asymmetric right and V-shaped asymmetric left. The purpose of this paper is to reinvestigate these phenomena and to provide an explanation for the observed asymmetry. For the present study a data base composed of all the V-shaped events recorded on board DEMETER during the period 2005-2010 had to be built. The events were selected through a close inspection of the VLF-spectrograms calculated from electric field data.

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2. V-shaped events description

Typical spectrograms of V-shaped events are presented here after. The VLF spectrograms of the electric field recorded on board ICE instrument *Berthelier et al.* [2006] for the three events chosen are represented in figure.1, the frequency range is 1-20 kHz, and the intensity of the electric field is color-coded according to the scale on the right of the panels, universal time, geographic latitudes and longitudes of the events are indicated in the bottom of the figure1.

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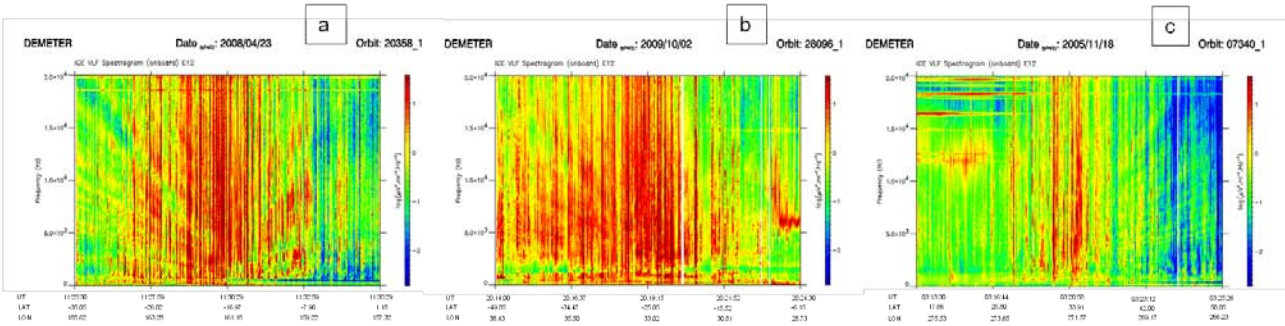

Figure 1: Spectrogram of an electric component in the VLF range up to 20 kHz for three typical events , intensity of the electric feld is given in a color code. The parameters below the spectrograms indicate universal time (UT), local time (LT), geographic latitude and longitude, Panel a represents a right asymmetric example, observed for the 18 nov 2005, panel b represents symmetric example for the 23 april 2008 and panel c represents a asymmetric left event for the 02 oct 2009.

For all the represented events, the phenomena of interest (V-shaped form) is about 10 minutes duration, covering a geographical distance of thousands of km. The V-shaped forms are observed during nighttime near 22 MLT, we can quote that many 0+ whistlers occurs at the center of the observations, when the satellite is just above the active thunderstorm area. Different slopes of the arms forming the V-shaped streaks are observed, each arm is the reflect of the interferences modes within the Earth-ionosphere wave guide, the value of the slope is in agreement with the relation x/f =cte, where x is the distance to the lightning source and f the frequency, as mentioned by *Parrot et al.* [2008b].

3. Statistical study of the V-shaped events

A database of V-shaped observations is constructed via a visualization of the spectrograms of the half orbits corresponding to night time observations. an online visualization is necessary in order to test the presence or not in the spectrograms of the V-shaped forms. 15120 half orbits were checked for a data set covering the period November 2007-November 2010, completing the work of *Parrot et al.* [2008b]. A total of 383 events are detected and constitute our database.

To geographically localize our different events, the position of the satellite is determined at a reference time T_{ref} corresponding to the time of intensification of the 0+ whistler, generally at the center of the V-shaped form observed. The corresponding orbital parameters are computed by the DEMETER data center at this time [*Lagoutte el al.,* 2006].

The map, represented in figure 2 gives a summary of the different occurrences of the 3classes of events (symmetric, asymmetric left and asymmetric right) in the different geographical regions.

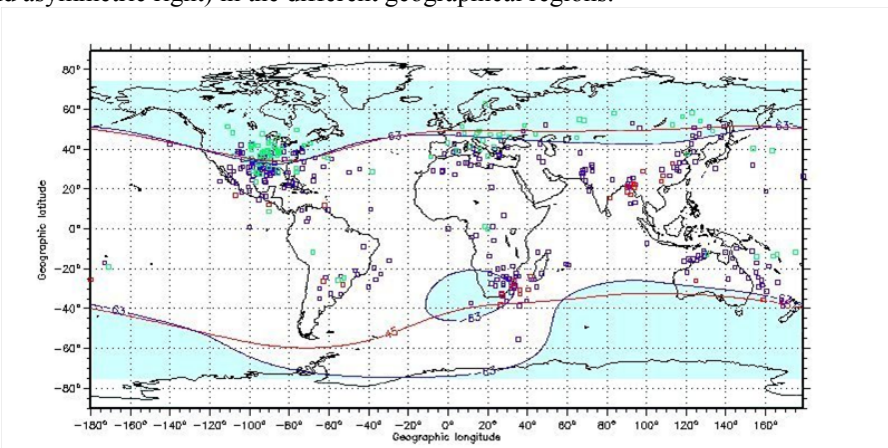

Figure 2: geographical localisation of the 383 observations of V events during the period 2005-2010 Asymmetric right events are represented with red squares, Asymmetric left events are represented with green squares, symmetric events are represented with blue squares. Geomagnetic latitude at 45° is represented in red color, contours of iso inclination at 63 and -63 are represented in blue, regions with |I|>63° are in blue color

5 Conclusion

We report here for the first time asymmetric observation of V-shaped events: statistical studies, modeling and particular event studies are performed in order to understand this asymmetry. The statistical study over 5 years point out a relationship between high active thunderstorm area and the observations of V-shaped emissions, higher occurrences are observed in the northern hemisphere where the ratio land /oceans is higher than in the southern hemisphere, a seasonal effect appear with high occurrences of V-shaped emissions on the northern hemisphere for the May-October period corresponding to northern summer, where lightning activity is more important. Occurrence of asymmetric observation are more important in high geomagnetic latitude regions, we make the assumption that the magnetic field play a role in the observed from of the V-shaped emissions, where the 0+ whistler mode observed follow the magnetic filed line to reach altitude satellite*.

7. References

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