Detection of Whistlers with a VLF Antenna Located in Belgium - Retrieval of Plasmaspheric Electron Density Profiles

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1. ABSTRACT.

Whistlers are **VLF** (3-30 kHz) **emissions initiated by lightning**, **propagating along magnetic field lines**, observed on ground and in space. Whistler wave analysis is an effective tool for studying the plasmasphere.
Whistlers acquire particular frequency-time characteristics while they propagate through the magnetospheric plasma, and in particular through the plasmasphere. **Their propagation time depends on the plasma density along their propagation paths**. It is possible to derive the plasmaspheric electron density distribution from these propagation times.
We therefore have started a **project to detect whistlers with VLF measurements**. A VLF antenna has been installed in end 2010 / early 2011 **in Humain, Belgium** (50.11°N, 5.15°E). The VLF antenna is made of **two perpendicular magnetic loops**, oriented North-South and East-West, and with an area of approximately 50 m^2 each.
This antenna is part of **AWDAnet, the Automatic Whistler Detector and Analyzer system's network**. This network covers low, mid and high magnetic latitudes, including conjugate locations.
In the near future, we will use the AWDA system to **retrieve automatically electron density profiles from whistler measurements made in Belgium**. In this paper, the first results of whistler occurrence will be shown.

2. INTRODUCTION.

A. Whistlers.

Whistlers are **VLF** (3-30 kHz) **emissions initiated by lightning**, propagating along magnetic field lines, observed on ground and in space. **The name whistler comes from the fact that the transposition of the signal into the audio frequency gives the impression of a whistle.**

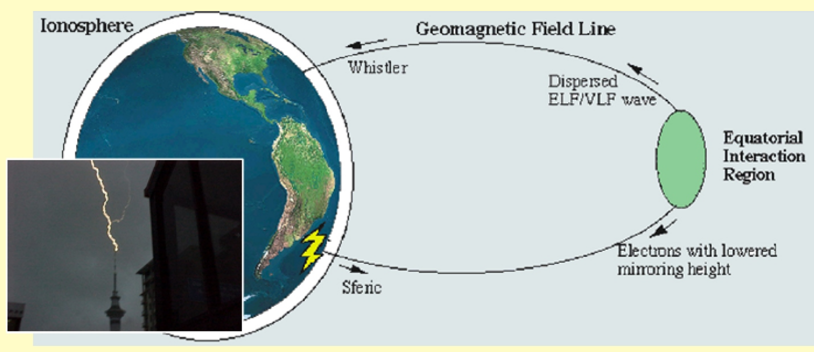

FIG. 1: *Sketch of a whistler generation and propagation.*

Whistlers acquire particular frequency-time characteristics while they propagate through the magnetospheric plasma, and in particular through the plasmasphere. **Their propagation time depends on the plasma density along their propagation paths**. It is possible to derive the plasmaspheric electron density distribution from these propagation times **[REF. 1]**.

B. VLF Antenna.

The project started in November 2009 and the first results were obtained in April 2011:
* November 2009: Meeting with the responsible of the AWDANet project;
* March-October 2010: Selection of material, decision about the size of the antenna, search of the location;
* **November 2010: the 12 meters mast installed in Humain, Belgium** (50.11°N, 5.15°E);
* January-March 2011: Installation of the hardware and software;
* **8 April 2011: First measurements made by the Belgian VLF antenna**.

FIG. 2: *Picture of the VLF antenna located in Humain, Belgium.*

The VLF antenna is made of **two perpendicular magnetic loops**, oriented **North-South and East-West**, and with an area of approximately **50 m^2** each.

C. AWDANet.

This antenna is part of **AWDAnet, the Automatic Whistler Detector and Analyzer system's network** **[REF. 2]**. This network covers low, mid and high magnetic latitudes, including conjugate magnetic locations. It consists of **same type of antennas with same data analysis software.**

In Europe, 7 antennas are in operations (including Humain) and 4 antennas are in preparation.

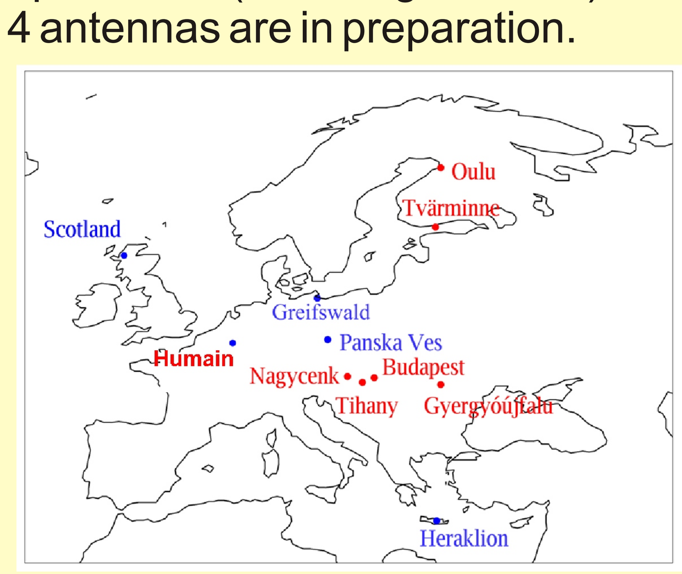

FIG. 3: *Location of the antennas part of the AWDANet in Europe.*

In the world outside Europe, 9 antennas are in operations and 9 antennas are planned or in

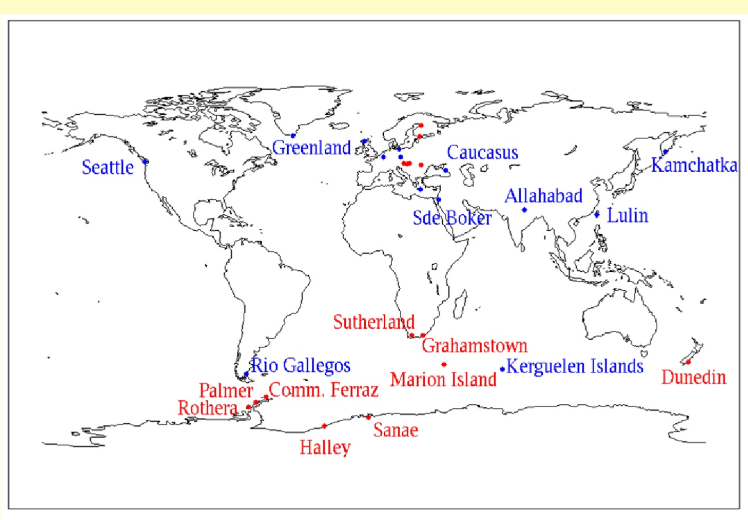

FIG. 4: *Location of the antennas part of the AWDANet in the world outside Europe.*

3. FIRST OBSERVATIONS AND ANALYSIS.

A. Dataset.

With the antenna recently built in Humain, Belgium, we **started the measurements on 8 April 2011**. We have obtained until now **7 weeks of data**:
* 8 - 14 April 2011;
* 5 May - 15 June 2011.

There is at the station an **automatic software for the detection of whistlers or signals similar to whistlers [REF. 2]**, to reduce the quantity of data to be stored.

B. Single trace analysis

Three particular events have been analyzed in details to derive some properties of whistlers and of the region crossed by the whistlers **[REF. 1]**:

* L (L-shell) [Re]	2.32	2.18	2.41
* N_{eq} (equat density) [cm^{-3}]	2470.7	2702.7	2455.8
* Fh_{eq} (equat gyrofreq) [kHz]	69.85	83.90	62.08
* F_n (nose frequency) [kHz]	24.86	29.54	22.23

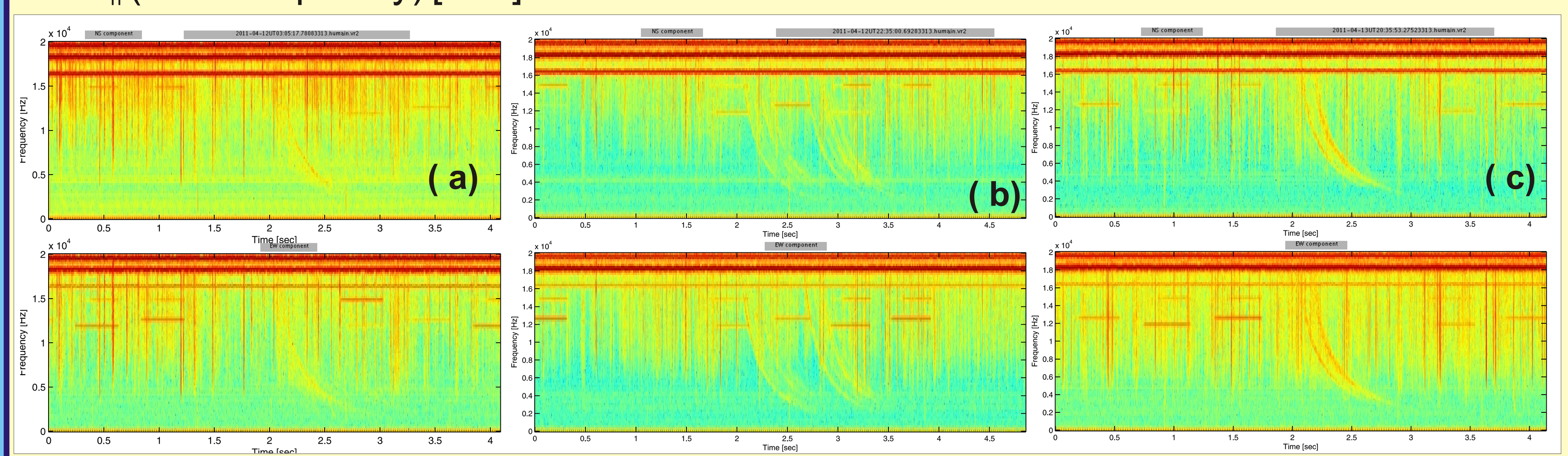

FIG. 5: *Frequency-time spectrograms measured at Humain, Belgium, showing whistler signatures, on (a) 12 April 2011 at 03:05 UT, (b) 12 April 2011 at 22:35 UT, (c) on 13 April 2011 at 20:35 UT.*

C. Statistical analysis

We do not observe whistlers between11 May 2011 and 15 June 2011. It confirms that we observe more whistlers during early spring.

We observe **1 day with more than 1500 whistlers signatures**, and 3 other days with more than 100 whistlers. **Several days do not show whistlers**. It was a low geomagnetic activity period.

Usually we observe **less than 2 traces in an event** (> 65%), and almost never more than 10 (<2%).

We observe **most of the whistlers during the night and evening**, before 5 UT and after 17 UT, and mostly **between 22 UT and 01 UT** (>70%).

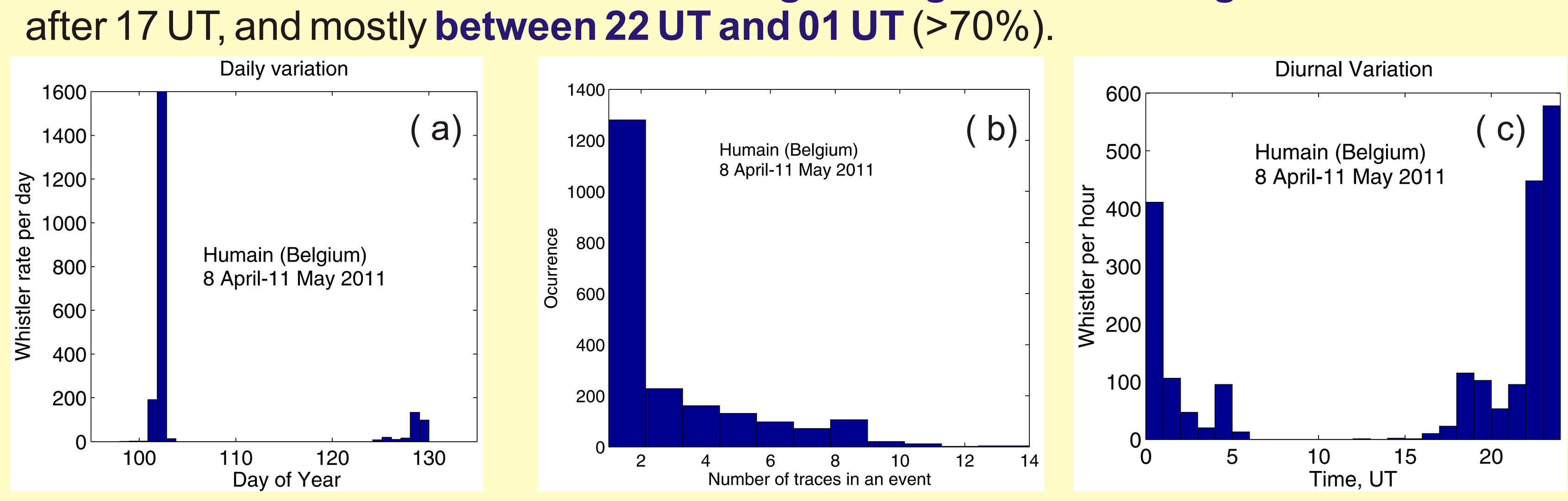

FIG. 6: *Statistical analysis of the whistlers observed at Humain, Belgium from 8 April to 11 May 2011. (a) Daily variation of the whistlers; (b) occurence of traces in a single whistler event; (b) diurnal variation of the whistlers.*

4. CONCLUSIONS

We have built the **first VLF station in Belgium to measure whistlers**.The antenna is working since 8 April 2011. The **observations are of good quality**, whereas we did not observe so many whistlers (not preferable season). We have analysed the first events in details, and managed to **get first information about the density inside the plasmasphere**. **First statistical results confirm previous studies** and results.

In the future, several tasks are planned:
* Continue automatic whistlers detection;
* Derive plasma density from whistlers observations in a more regular basis **[REF. 1]**;
* **Continue statistical analysis with a larger database**;
* Start compared studies with other antennas of the AWDANet **[REF. 2]**;
* Start **conjugated analysis with in-situ measurements of plasma density** in the plasmasphere (Cluster data for example) **[REF. 3]**;
* Start **comparison analysis with density obtained from numerical simulations**.

REFERENCES

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