# Qualitative study of the seasonal behaviour of the ionosphere's D region from 3 years of VLF-LF signals monitoring

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## ABSTRACT

We present a qualitative study of the seasonal behaviour of the D region. Systematic examinations of continuous recordings of diurnal analogical data (1998, 1999 and 2000) in amplitude signals at LF (MSF of 60 kHz) and VLF (GBR of 16 kHz) were carried out. In order to decipher the dynamical signature of the D layer on these signals, we have worked out an original method basing itself on the study of the seasonal behaviour of various morphologies. Our results show that various ionospheric or atmospheric phenomena affect the transmission of these signals.

## INTRODUCTION

The D region of the ionosphere, which merges at first approximation with the mesosphere of the aeronomists, takes on a very particular importance during the transmission of a radioelectric signals at VLF and LF. This area, which is used as interface between the neutral atmosphere and the low ionosphere, resisted in situ to any explorations, the most powerful balloons probes reaching a maximum to 40 km of altitude while the spacecraft orbit with difficulty below 300 km. As for the shootings of probe rockets, one counts only 72 of them since the Sixties with regard to the areas of medium latitude.

The D region always occupied a marginal place in the community of the ionospherists, essentially related to the difficulties of monitoring which require strong powers and hectometric aerials of delicate realisation.

Within the framework of Ionospheric Weather, one of the concerns of the COST 271 (european Cooperation in the field of Scientific and Technical research) is to model the D area in the European zone extending from the Atlantic to the Caspian one.

A pole of interest was developed between the Service of Astrophysics of the University of Mons Hainaut (UMH) and the Department of Geophysics of the Royal Meteorological

Institute of Belgium (RMI). The repercussions of this collaboration are a better knowledge of the D region and a development of instrumental techniques adapted with its study. Extremely short band-pass of the receivers with direct amplification is used. Precise GPS tuning combined with the very stable frequency of the sunders allows phase measurements [1]. Their joint efforts lead to establish a reception station in the region of Tournai on Belgium (Latitude: 50°37.431'N, Longitude: 3°30.417'E) [2]. This station based on a continuous monitoring of four VLF and LF radioelectric signals.

In the following sections of this paper, we present the characteristics of only two received signals (GBR of 16 kHz and MSF of 60 kHz), then the signature of the D region on their amplitudes traduced by the observed morphologies: our qualitative method. In the third section, we give our statistics for the seasonal behaviour of some morphologies and we try to identify the nature of some ones, followed by conclusions and some remarks.

## CHARACTERISTICS OF THE RECEIVED SIGNALS

The very low frequencies (VLF: 3kHz-30kHz) and the low ones (LF: 30kHz-300kHz) are always used in the long wave communication systems. The radioelectric signals emitted with those frequencies have the characteristic to be reflected in D region.

On a passive monitoring of those signals the experimenter makes use of a diverted emission of its first finality on which he doesn't have any recording. Thus, within the framework, as well of Ionospheric Weather as of Ionospheric Climate, information about the signal's absorption during the reflection process can be only exploited in so far as the amplitude of the emission remains usually constant (from the split of a second to the year). And the emission is continuous with an occupation rate of the circuit closed to 24h/24h.

The received wave is a composite one which is the vectorial sum of a constant wave of ground presenting a slight seasonal signature and of a essentially fluctuating wave of sky which phase is representing the sky's path and the conditions of reflection. The phase or the figure of interference of a ground wave and a sky one can be fully studied only in so far as the phase of the emitted signal is stable or that one can easily rebuild it on the site of reception.

The area COST 271 which extends between the latitudes 35-70°N and longitudes 10°W-60°E is covered by five transmitters answering these particularly strict criteria. They are transmitters of time signals or signals associated. Four of these transmitters are located at less than 500 km of the reception's site of the UMH-RMI.

In this paper, we present our results for two radioelectric signals (GBR of 16 kHz and MSF of 60 kHz) received at Tournai's station. Those signals are emitted from the same station at Rugby on UK (Latitude: 52°22'N, Longitude: 01°11'W).

## QUALITATIVE METHOD

In the systematic examination of the analogical continuous recordings produced during

almost the last three years (1998, 1999 and 2000) using the experimental station in Tournai, we started initially with the VLF signal: GBR of 16 kHz, followed by the first LF one: MSF of 60 kHz.
Our qualitative study concerning these examinations led us to work out an original method basing itself on the study of the seasonal behaviour of various morphologies of each signal. With the aim to decipher the dynamic signature of the D layer and the ionospheric and atmospheric phenomena on the concerned signals, we could identify 13 different morphologies (see Fig. 1.), of which their appearances depend on the seasonal changes. This enabled us to classify them in two groups. The first ones are of a physical nature (morphologies: A, C, D, E, F, G, K, L and M) which reflect the influence of the various ionospheric and atmospheric phenomena on the transmission of the above signals. And the seconds are of an instrumental nature (morphologies: B, H, I and J) due to the technical problems related at the same time to the transmitting and receiving stations (we could locating the periods of maintenance of the transmitters).

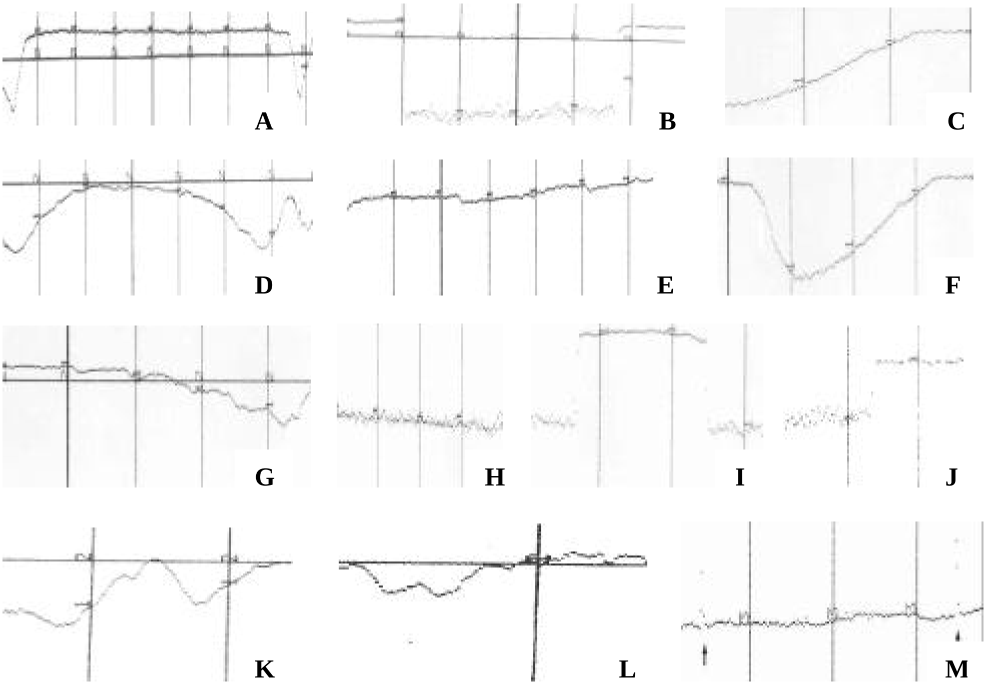


Fig. 1. Different morphologies observed on the received signals

## DISCUSION

With our qualitative method, we highlighted the existence of 13 morphologies on the received signals. Four of them (morphologies: B, H, I and J) are of an instrumental nature see Fig. 1. The others are of a physical nature (morphologies: A, C, D, E, F, G, K, L and M). The morphology A where the amplitude of the signal remains constant all the day, led as to describe this day as a calm one, no observed phenomena. The morphology C is generally related to a change of the amplitude due to a physical phenomenon such as the solar flares. The morphology D, which is similar to morphology A, has a certain quasi-smooth curve in the amplitude and reflects the character of the progressive change of the electronic concentration in the D layer of the ionosphere. The morphology E shows the effect of the disturbances due to the tropospheric storms on the signals at very low frequencies called the Trimpi Effect [3]. It represents an abrupt variation of the amplitude of the signal and reflects the character of the brutal change of the electronic concentration in region D of the ionosphere. This led us to note initially that this influence is clear in the case of the signal at VLF then of the LF signal. On the other hand, and according to our seasonal statistics, the rate of the Trimpi events is more outstanding during the season of summer 2000 (high solar activity) for the two signals. In the majority of the cases, The morphology F characterises the influence of the x-rays coming from the solar flares on the D layer. In certain cases, one cannot find any reference of a flare activity thus the origin is unknown. The morphology G represents the variation of the amplitude in "stairs" and highlighting the existence of a gradient of the electronic concentration in the D layer, and consequently the existence of a gradient of index of refraction, which gives to the connection Ground-Ionosphere the character of a waveguide. The morphologies K and L appear sometimes at the sunrise and sunset times. The last one, morphology M, highlighted abrupt variation of the amplitude of the signal. Indeed, we suspect that it is also due to the effect of the tropospheric lightning on the ionosphere, which remains to be confirmed. In addition, this work will be useful for us like a rough model of forecast for the signals that are now received at Dourbes's station.


## ACKNOWLEDGEMENTS

This work was supported by the Federal Office for Scientific, Technical and Cultural Affairs.


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