LONG-TERM TRENDS OF THE IONOSPHERE AT MID AND HIGH LATITUDE REGIONS

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ABSTRACT

In this paper, for investigating on the influence of the geomagnetic activity on the ionospheric long-term trends, an analysis of long series of ionospheric data acquired at mid and high latitude is carried out to verify the previous results obtained over the poles [1,2]. The results are presented, compared and discussed to give another contribution to the general debate on the natural (i.e. long-term enhancement of the geomagnetic activity) and/or anthropogenic origin (i.e. meso-thermospheric cooling due to the greenhouse effect) of the ionospheric trends.

INTRODUCTION

From the beginning of the 90's the secular behaviour of the ionosphere is studied by different scientific groups all over the world to look for ionospheric long-term trends. At the very beginning these investigations have been mainly addressed to verify a possible connection between the ionospheric long-term behaviour and the increasing thermospheric-mesospheric cooling due to the enhancement of the greenhouse gases emission [3,4]. In particular, according to Rishbeth [3,4], under perfect gas law applicability and hydrostatic equilibrium regime approximation, the increasing of CO_2 and CH_4 mixing ratios at the Mesopause (around 60 km) should cause ionospheric parameters long-term variations (negative trend in the F2 real height and in the F2 maximum of the electron density, etc.) [3,4]. On the other hand different physical mechanisms could be responsible of the ionospheric long-term effect: connection between magnetopause position and ionospheric ionisation level [5], planetary waves and quasi-biennial oscillation of the semidiurnal tide [6], long-term decreasing trend of the horizontal thermospheric wind [7], long-term increasing/decreasing of the geomagnetic activity [8] enhancement of magnetic activity storm over the last century [9]. Recently our investigations of the foF2 long-term behaviour based on both monthly median and hourly data coming from different high latitude stations have shown a general depletion of the maximum of the electron density over 3 solar cycles [1,2]. In our last analysis we have investigated on a possible geomagnetic control of the ionospheric long-term behaviour. For this scope we have used the Magnetic Activity Catalogue for ionospheric applications, MACap(τ), to indicate the magnetic disturbance impact on the ionosphere [10]. From these recent investigations [2,10] the long-term behaviour of Macap(τ) does not indicate any clear increasing trend of the geomagnetic activity influence on the ionosphere. Consequently, from our results the geomagnetic activity doesn't seem to give any long-term effect on the plasma frequency of the F2 layer [2].
In this paper the data processing is described in section 1; the obtained results are presented and discussed in section 2.

1. THE DATA ANALYSIS

After a validation of the available data, simply based on the calculation of the standard deviation respect to the ITU-R modelled data [11], the f0F2 hourly values coming from mid and high latitude stations are considered for the period from the late 50's to the late 90's (tab. 1). A selection of the data base is carried out to avoid the inaccuracies due to technical problems of the apparatus and/or caused by physical disturbance phenomena. For this reason only full weight foF2 values, i.e. values without qualifying letters, are considered in this investigation [12]. In fact, those values accompanied by qualifying letters are affected by greater errors and, in our opinion, cannot be considered for long-term investigations.

Table.1 Geographic and geomagnetic locations of the ionospheric stations considered.

Station	Geographic Co-Ordinates	Geomagnetic Co-Ordinates	Period Under Investigation
Lycksele	64.6°N, 18.8°E	62.5°N, 111.7°E	1962-1998
Slough	51.5°N, 359.5°E	54.0°N, 84.4°E	1957-1998
Rome	41.8°N, 12.5°E	42.3°N, 93.2°E	1976-1998
Mawson	67.6°S, 62.9°E	73.3°S, 105.1°E	1962-1998

For investigating the geomagnetic control of the long-term behaviour of the ionosphere, a new Magnetic Activity Catalogue, MACap(τ), derived by a time series accumulation of the geomagnetic ap index, ap(τ), is considered [13,10]. MACap(τ) characterizes the magnetic activity by using four reference levels depending on the magnetic conditions (tab. 2). In this investigation the data analysis is carried out on the foF2 data corresponding to quiet magnetic condition, i.e. MAC=0 (tab. 2).

The data processing can be summarised in the following main steps:

- Calculation of the fof2 monthly medians based on hourly values characterised by MAC=0, i.e. quiet magnetic conditions; in this way the effects on the f2 layer due to geomagnetic activity should be removed;
- Application of a regression polynomial model (R,R^2) to reproduce the solar foF2 solar cycle dependence [14];
- Calculation of the residuals given by the difference between foF2 experimental and regression modelled values [14];
- Linear fitting applied on the yearly means of the foF2 residuals to obtain the long-term trend [14];
- Application of the Fisher test to verify the significance of the results [15].

2. RESULTS AND DISCUSSION

The results obtained from this analysis are reported in table 3 and shown in figure 1. All the ionospheric stations included in the analysis show a long-term decrease of foF2 between –0.1 MHz and –0.2 MHz. According to the Fisher test the significance of the results stands on quite acceptable confidence levels (between 90% and 95%).
The selected foF2 data are related to quiet magnetic condition (MAC=0, see tab. 2) and the foF2 residuals should be independent from the solar cycle influence after the application of the regression model (R,R^2). So that, what is the real cause of the observed foF2 negative trends? The trend rate here found is in good agreement with the theoretical prediction made by Rishbeth [4] indicating a decrease of foF2 around –0.1 MHz due to the mesospheric-thermospheric cooling caused by the increasing emission of the greenhouse gases. Naturally, further investigations need to verify this hypothesis. In any case it's our opinion that the long-term investigation on the ionospheric trends should be based on data set accurately validated. Moreover, this investigation confirms the crucial importance found in our previous analysis [2] in using MACap as a proper indicator of the geomagnetic activity impact on the ionosphere also for long-term studies application [16].

Table 2. Reference Levels of MACap(τ=0.8).

ap(0.8) Interval Limits	Levels Definition of Magnetic Condition	MACap(τ=0.8) Corresponding Levels
$0<ap(0.8)\leq 7$	Quiet	0
$7<ap(0.8)\leq 20$	Slightly Disturbed	1
$20<ap(0.8)\leq 32$	Moderately Disturbed	2
$ap(0.8)>32$	Severely Disturbed	3

Table 3. foF2 total trend along the entire period considered for each station by considering the MAC=0 magnetic condition.

Station	Period Under Investigation	Total foF2 Trend (MHz)
Lycksele	1962-1998	-0.10
Slough	1957-1998	-0.11
Rome	1976-1998	-0.15
Mawson	1962-1998	-0.20

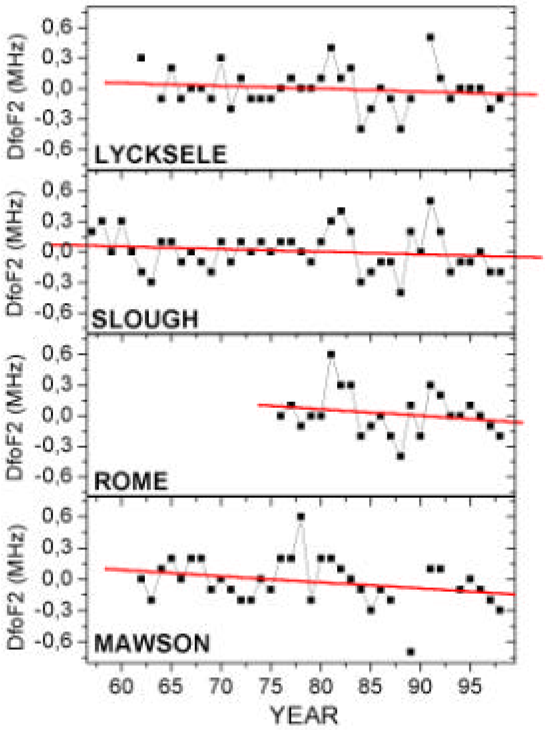

Fig. 1. Trends of the yearly foF2 residuals, DfoF2, for each ionospheric station considered after the elimination of the solar dependence with a (R,R^2) regression model form the experimental foF2 data corresponding to MAC=0 magnetic condition.

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