Periodic variations of ionospheric Wait's parameters caused by changes in the intensity of incoming solar hydrogen Ly radiation

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Abstract

Hydrogen Lyα photons corresponding to the 121.6 nm line in the solar spectrum are the most significant source of photo-ionization process in the D-region of the Earth's ionosphere. This radiation is continuously emitted and variations in its intensity in the ionosphere result from varying emission intensity of this radiation in the Sun and as well as from the Earth motion due to its rotation and revolution around the Sun. These changes affect variations in ionospheric parameters. In this paper, we analyse the variations of Wait's parameters which can further be used to determine the electron density and, consequently, more other ionospheric parameters in this region. Our analysis is based on the Quiet Ionospheric D-Region (QIonDR) model and shows the dependences of the observed parameters on the smoothed daily sunspot number, that represent variations in radiation during the solar cycle, and the day of year.

Introduction

Solar radiation is the main source of ionization in the Earth's ionosphere, and the most significant influence during calm conditions in the processes of photo-ionization in the lowest layer of this part of the atmosphere (D-region) has the hydrogen Lyα radiation. Consequently, this radiation plays a very important role in the dynamics of electron density whose study is important for scientific analysis of ionospheric physical and chemical characteristics, and for practical applications, primarily related to the propagation of electromagnetic signals used e.g. in the fields of telecommunications and space geodesy.

One of the methods for determining the electron density is based on monitoring the ionosphere with very low/low frequency (VLF/LF) signals and using Wait's model of the ionosphere (Wait and Spies, 1964). This model is based on the assumption of a horizontally uniform ionosphere described by two independent parameters: the "sharpness", β, which describe the electron density vertical gradient, and the signal reflection height, H'.

In this paper, we provide an analysis of the influence of the incoming Lyα radiation in the observed part of the D-region on variations of Wait's parameters based on the QIonDR model (Nina et al., 2021).

Modelling

According to the QIonDR model, parameters β *and* H' can be calculated using the expression:

$$\beta = 0.2635 + 0.002573\sigma - 9.024 \cdot 10^{-6}\sigma^2 + 0.005351 \cdot \cos(2\pi(\xi - 0.4712)) \quad (1)$$

and

$$H' = 74.74 - 0.02984\sigma + 0.5705 \cdot \cos(2\pi(\xi - 0.4712) + \pi), \quad (2)$$

where σ and ξ are the smoothed daily sunspot number (over 21 days) and the seasonal parameter defined as DOY/365, where DOY is the day of year.

In this paper we analyse relative changes in Wait's parameters with parameter σ and DOY, d, according equations:

$$\frac{1}{\beta(i,j)}\frac{\Delta\beta(i,j)}{\Delta\sigma} = \frac{\beta(i+1,j)-\beta(i-1,j)}{2\beta(i,j)} \quad (3)$$

$$\frac{1}{H'(i,j)}\frac{\Delta H'(i,j)}{\Delta\sigma} = \frac{H'(i+1,j)-H'(i-1,j)}{2H'(i,j)} \quad (4)$$

$$\frac{1}{\beta(i,j)}\frac{\Delta\beta(i,j)}{\Delta d} = \frac{\beta(i,j+1)-\beta(i,j-1)}{2\beta(i,j)} \quad (5)$$

$$\frac{1}{H'(i,j)}\frac{\Delta H'(i,j)}{\Delta d} = \frac{H'(i,j+1)-H'(i,j-1)}{2H'(i,j)} \quad (6)$$

where i and j represent the i-th and j-th values of σ and DOY, respectively.

Results and discussion

The obtained results are presented in Figs. 1 (for changes of parameter β) and 2 (for parameter H').

The left panel of Fig. 1 shows relative variations of parameter β due to changes of sunspot number decrease with σ and they do not significantly change during the year. Contrary, the relative changes of this parameter in time are more pronounced with day than with σ. As one can see in the right panel of Fig. 1, the absolute values of the considered changes are the largest in the periods of equinox and at small sunspot numbers.

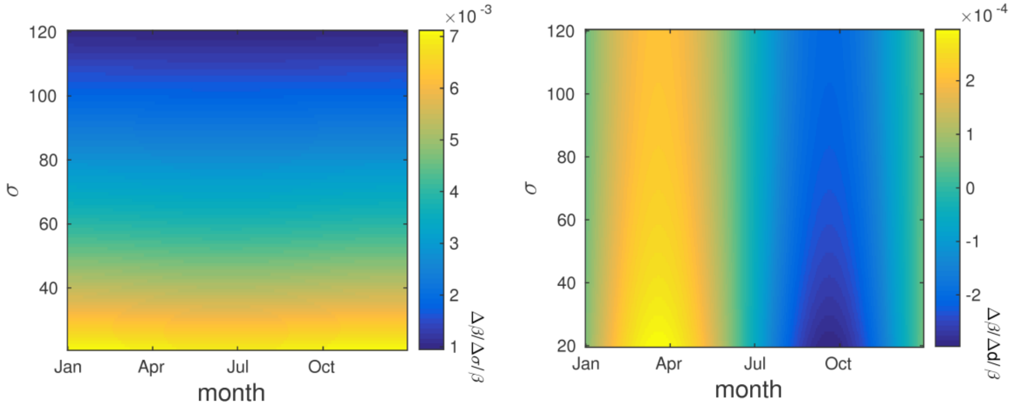

Fig. 1. Relative changes of Wait's parameter "sharpness", β, with changes of the smoothed daily sunspot number, $\Delta\sigma$ (left panel) and the day Δd (right panel) depending on the parameter σ and the day of year.

Relative changes of H' with changes of σ are more pronounced than the corresponding changes with days. As one can see in Fig. 2, the maximum changes in the first case are in the winter period, while the observed variations in the second case are most pronounced during the equinoxes.

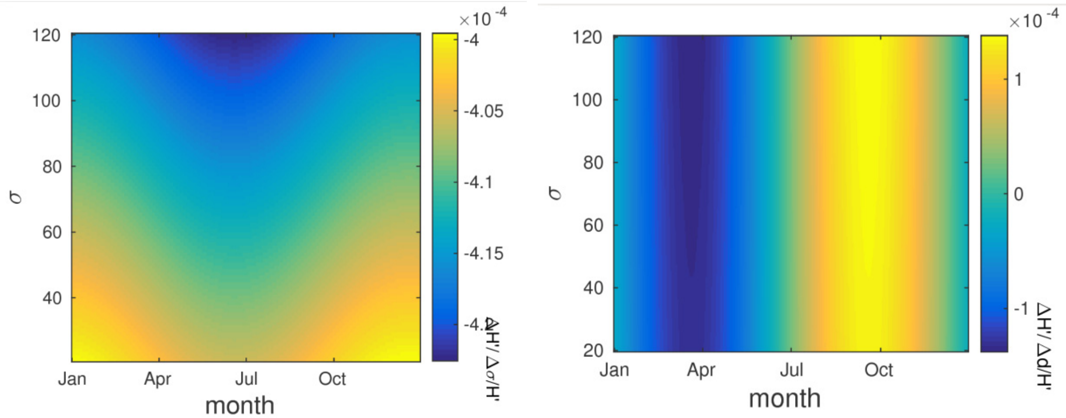

Fig. 2. Relative changes of Wait's parameter signal reflection height, *H',* with changes of the smoothed daily sunspot number, Δσ (left panel) and the day Δ*d* (right panel) depending on the parameter σ and the day of year.

Although the values shown are not large (they are of the order of 10^{-3} and 10^{-4}), they are continuous and cause noticeable disturbances for longer periods of several days or months, which may be significant for analyses of periodical changes in ionospheric characteristics.

Conclusions

In this paper, we present an analysis of the periodic changes in Wait's parameters caused by changes in the intensity of solar radiation and the Earth's revolution. The presented results were obtained by applying the Quiet Ionospheric D-region model, and they allow the following conclusions:

- Relative changes in the "sharpness" and the signal reflection height with the sunspot number reach the values of the order of per mille and tenth of per mille, respectively. In both cases they decrease with the sunspot number and the maximum values are reached during the winter solstice.
- The daily relative changes of both Wait's parameters are less than a per mille, their variations are more noticeable during the year than during the solar cycle, and they are most pronounced at equinox periods.

Keeping in mind that knowledge of Wait's parameters allows calculation of the D-region electron density and, consequently, modelling of several other ionospheric parameters, the impact of changes presented in this study on variations in ionospheric characteristics will be the subject of future research.

Acknowledgments

The authors acknowledge funding provided by the Institute of Physics Belgrade, Geographical Institute Jovan Cvijić SASA and Astronomical Observatory (the contract 451-03-68/2020-14/200002) through the grants by the Ministry of Education, Science, and Technological Development of the Republic of Serbia.

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