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[*Contributed paper*]

Influence of the D-region electron density on modeled ionospheric Wait's parameters in quiet conditions – case study

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Abstract: In this paper, we show the difference in the ionospheric D-region electron density depending on two sets of parameter values in the quiet period before the influence of the solar X-ray flare. These data sets are obtained on the basis of the Quiet Ionospheric D-Region (QIonDR) model and its modification for the current period determined using analysis of the time evolutions of ionospheric parameters. We study D-region perturbation induced by the solar X-ray flare of class M1.4 that occurred on 1 July 2014. The obtained results show that the deviations increase with height and the highest value is reached during the maximum of the perturbation, but that in the observed example, the difference is greater than one order of magnitude only during intense perturbation for altitudes above 80 km.

Keywords: Solar X-ray flare, ionospheric D-region, VLF signal

Introduction

Modelling the atmosphere is very complex both in quiet and disturbed periods. At the same time, modelling in quiet conditions also affects the determination of parameter variations during perturbations.

In this paper, we show the impact of modelling the ionospheric D region in quiet conditions on the determination of the electron density during the perturbation caused by a solar X-ray flare. We analyze differences in calculations of the D-region electron density using the QionDR model and its modification by the procedure described in Nina (2022). The QionDR model provides general dependences of Wait's parameters on quiet conditions on the sunspot number and day of year in the midday periods (relevant for this study). The procedure given in Nina (2022) relates to the observed time period and it is based on the analysis of evolution of the Wait parameters sharpness β and reflection height H' during the impact of a solar X-flare. Here we consider the solar X-ray flare of class M1.4 that occurred on July 1, 2014.

Observations, data and modelling

The considered solar X-ray flare is recorded by GOES satellite in period 11:05 to 11:59 UT with maximum intensity corresponding to class M1.4 on 11:23 UT. To analyze ionospheric D-region electron density we process a very low frequency (VLF) signal used for monitoring of this atmospheric layer. We consider VLF signal emitted by the DHO 23.4 kHz transmitter located in Germany and received by the (AWESOME) receiver in Serbia. The recorded data in the considered period is shown in Fig. 1.

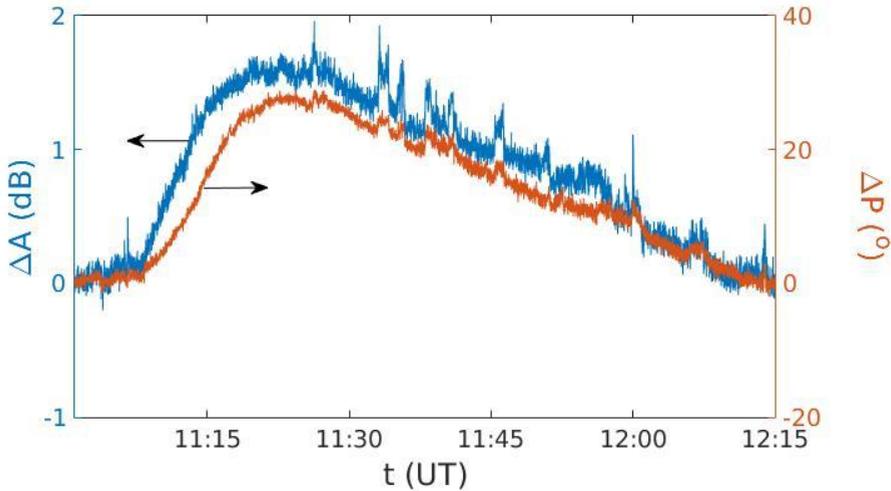


Figure 1. Differences of the recorded amplitude ΔA and phase ΔP during perturbation with respect to the corresponding values during quiet condition before influence of the considered X-ray flare.

The ionospheric Wait's parameters sharpness β and reflection height H' are modelled using procedure described in details in Nina et al., 2020. This procedure requires knowledge of the values of these parameters in quiet conditions before the considered perturbation period. To calculate them we apply two procedures based on the QIonDR model. First procedure is based on the basic QIonDR model (Q), and the second one use the modification of this model described in Nina (2022) (mQ).

The electron density N_e in both procedures is calculated using equations (Thomson 1993)

$$N_e(h,t) = 1.43 \cdot 10^{13} e^{-\beta(t)H'(t)} e^{(\beta(t)-0.15)h},$$

where h is height.

Results and discussion

According the QionDR model, the initial values (e.g. values in quiet

conditions) of parameters β_Q and H'_Q are 0.483 km^{-1} and 71.1 km . Applying the procedure described in Nina 2021, the obtained corresponding modified values β_{mQ} and H'_{mQ} are 0.450 km^{-1} and 70.0 km , respectively..

The modelled time evolutions of Wait's parameters, presented in Fig. 2, show that β is higher and H' lower in the second case during the whole considered time period. The absolute values of the differences $\Delta\beta = \beta_{mQ} - \beta_Q$ and $\Delta H' = H'_{mQ} - H'_Q$ (shown in the bottom panel) are the largest in the period of maximum perturbation and have values approximately from 0.1 km^{-1} to 0.2 km^{-1} , and from 1 km to 2 km , respectively.

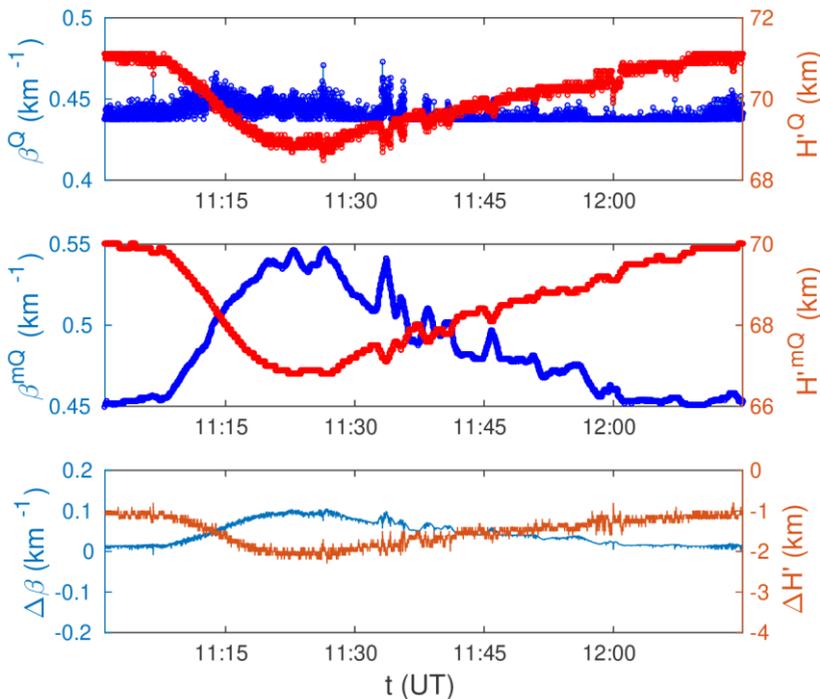


Figure 2. Time evolutions of Wait's parameters for initial values obtained by the QionDR model (upper panel) and modelled by procedure given in Nina, 2021 (middle panel). Time evolutions of differences of these parameters $\Delta\beta$ and $\Delta H'$ are given in the bottom panel.

Dependencies $N_e(t,h)$ for both sets of Wait's parameters are presented in Fig. 3. The calculations based on the QionDR model (N_e^Q) are shown in the upper panel, while the results obtained using this modified model (N_e^{mQ}) are given in the bottom panel. As one can see the electron density has higher values in the second case.

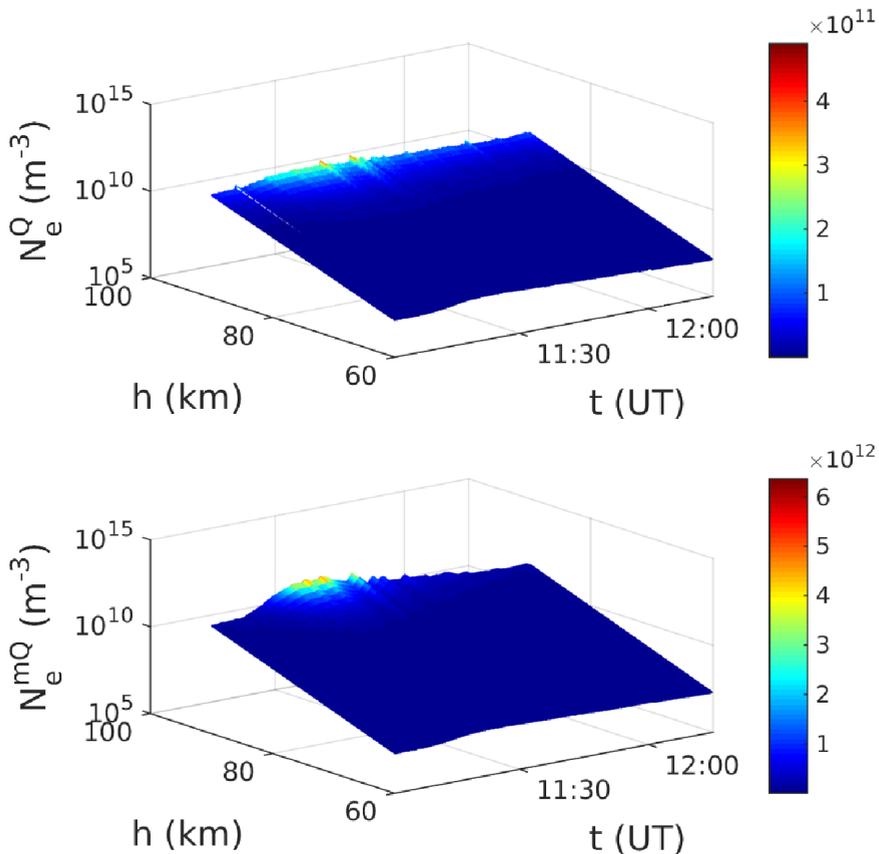


Figure 3. The electron density dependencies on the time t and height h for the initial Wait's parameters calculated by basic (upper panel) and modified (bottom panel) model.

The ratio $r = N_{emQ}/N_{eQ}$ (shown in Fig. 4) is the most pronounced in the period of maximum perturbation and rise with height. It indicates that difference of the obtained electron density is within one order of the magnitude except in the period of the most intense perturbation for altitude larger than 80 km.

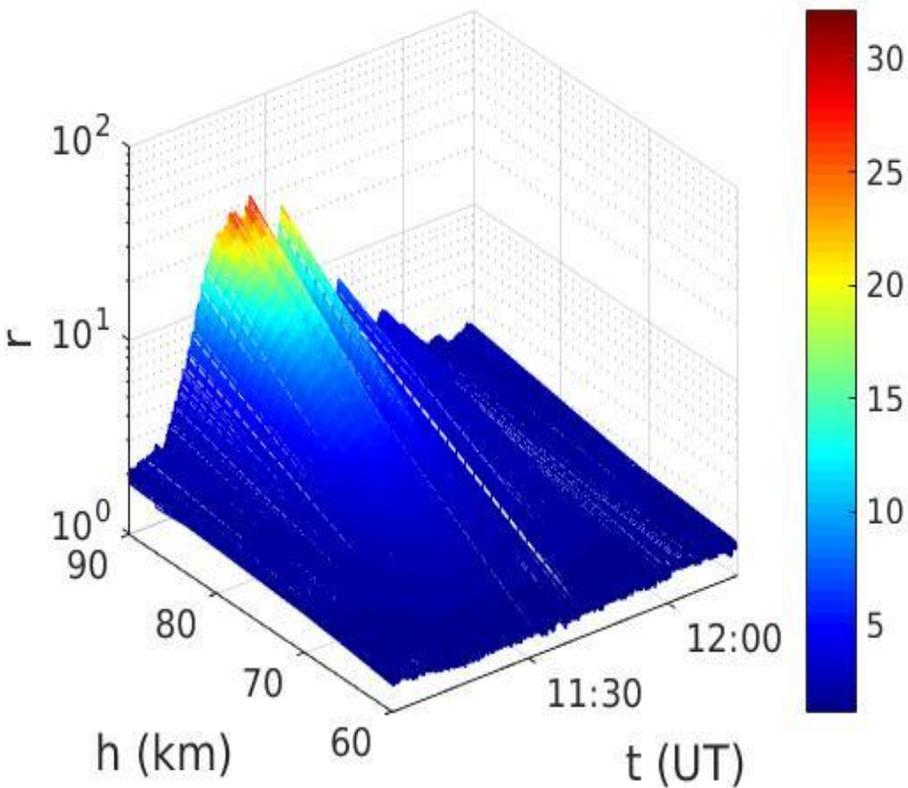


Figure 4. Dependencies of the ratio $r = N_{emQ}/N_{eQ}$ on the time and height.

This results indicate that the considered modification is important for strong perturbations at the upper D-region part.

Summary

In this study we show difference in modelling of the ionospheric D-region electron density applying two procedures for determination of initial ionospheric Wait's parameters in quiet condition. To calculate them we apply QionDR model and its modification which give the time evolutions of Wait's parameters during perturbations that best match the shapes of signal amplitude and phase. We consider an example of perturbation induced by a solar X-ray flare of class M1.4 that occurred on 1 July 2014. The obtained results show that differences are within one order of magnitude except during intense perturbation above 80 km.

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