Lyα RADIATION INFLUENCE TO IONOSPHERIC D-REGION: QUIET IONOSPHERIC D-REGION (QIonDR) MODEL

A. Nina[1] , G. Nico[2], S. T. Mitrović[3], V. M. Čadež[4], I. R. Milošević[1], M. Radovanović[5,6] and L. Č. Popović[4]

[1]Institute of Physics Belgrade, University of Belgrade, 11080 Belgrade, Serbia, sandrast@ipb.ac.rs
[2]Istituto per le Applicazioni del Calcolo (IAC), Consiglio Nazionale delle Ricerche (CNR), 70126 Bari, Italy
[3]Novelic, 11000 Belgrade, Serbia
[4]Astronomical Observatory, Volgina 7, 11060 Belgrade, Serbia
[5]Geographical Institute "Jovan Cvijić" SASA, 11000 Belgrade, Serbia
[6]Institute of Sports, Tourism and Service, South Ural State University, 454080 Chelyabinsk, Russia

We present the Quiet Ionospheric D-Region (QIonDR) model [1] to analyze periodical variations of ionospheric parameters induced by changes in the incoming solar hydrogen Lyα line intensity. The model is based on data collected in the ionospheric D-region observations utilizing very low/low frequency (VLF/LF) signals. It provides: (1) a procedure for estimation of ionospheric parameters during quiet midday periods as a function of the daily sunspot number, related to the long-term variations during solar cycle, and the seasonal parameter, providing the seasonal variations, and (2) a procedure for determination of ionospheric parameters during the entire daytime using their midday values. QIonDR model is applied to VLF data acquired in Serbia that are related to the DHO and ICV signals emitted in Germany and Italy, respectively. We show time evolutions of the daytime Wait's parameters over the middle and low latitudes, and analytical expressions for midday parameters valid over a part of Europe.

Motivation

- The parameters in quiet conditions can significantly affect the modeling in both quiet and disturbed state
- However, they are soon considered as known quantities which are determined in previous statistical studies that, generally, do not represent the considered periods and areas.

QIonDR model

- We developed a numerical tool to model the daytime ionospheric parameters over the middle and low latitudes,
- We provided an analytical expression valid over a part of Europe for midday parameters.

Observations

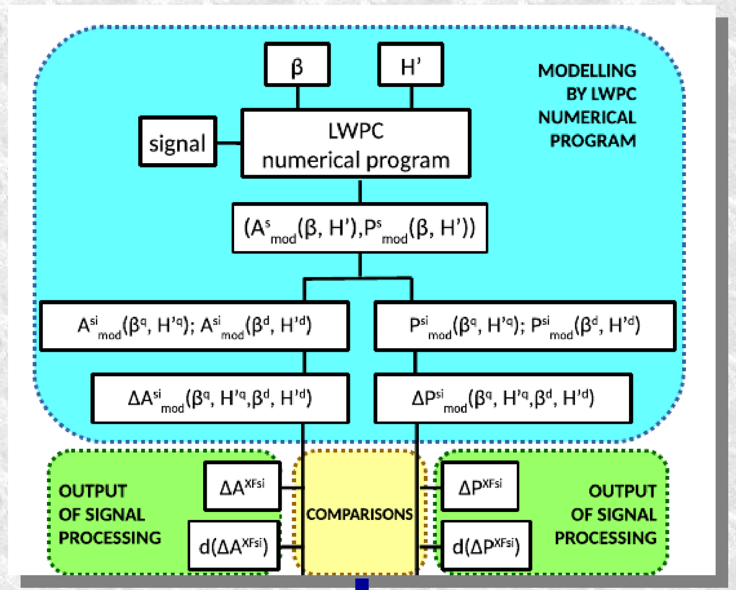
Remote sensing by very low / low frequency (VLF/LF) radio waves.

Input parameters in LWPC: signal properties, receiver position and Wait's parameters [3] ("sharpness" β and signal reflection height H') - ionospheric parameters which are used for calculation of the D-region electron density

Output parameters in LWPC: amplitude and phase.

Modelling

Presented procedure is based on numerical model for VLF/LF signal propagation Long-Wave Propagation Capability (LWPC) program [2].

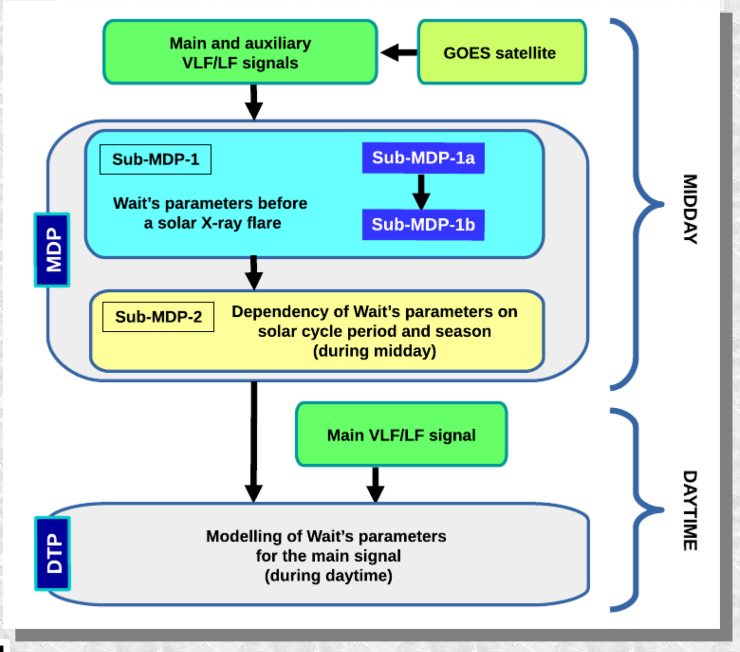


Pair (β,H') which provides the best agreement of recorded and modelled amplitude and phase changes

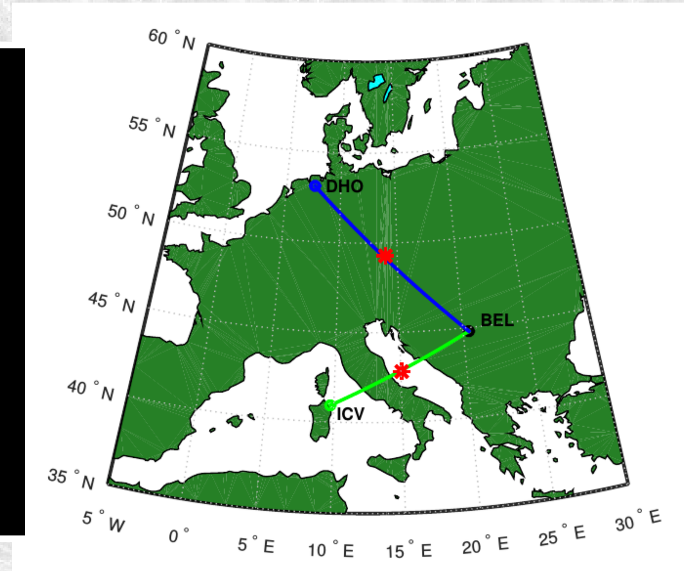
QionDR model description and application

It is divided in two parts related to:
Midday period – provides equations for estimation ionospheric parameters with respect to day of year and sunspot number;
Daytime period – provides time evolutions of ionospheric parameters between sunrise and sunset.

The proposed methodology is applied to areas monitored by two VLF/LF radio signals emitted and recorded by relatively closely located transmitters and one receivers.



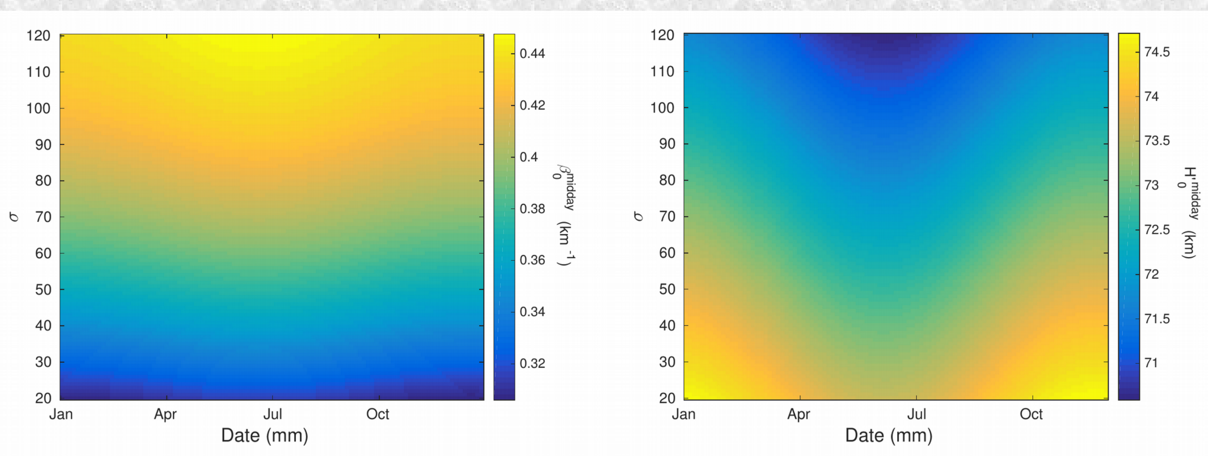
Model is applied on VLF signals emitted by DHO and ICV transmitters located in Germany and Italy, respectively and received in Belgrade, Serbia.



Results - Midday periods

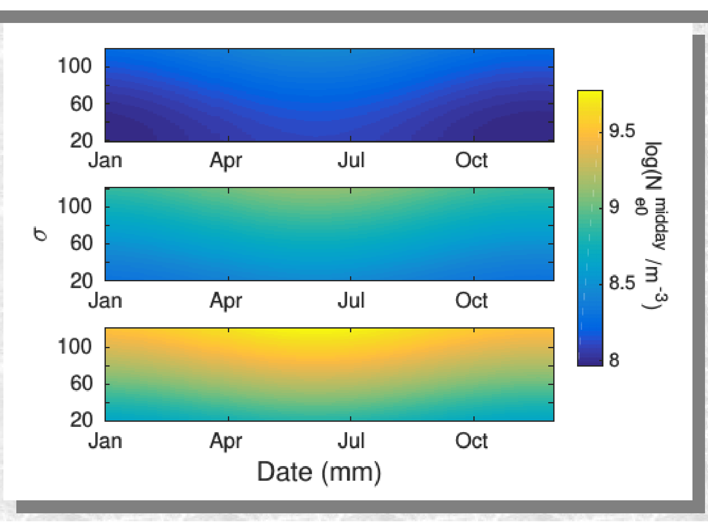
D-region over Europe

σ- daily smoothed sunspot number
χ - day of year



$$\beta_0^{\mathrm{midday}} = 0.2635 + 0.002573 \cdot \sigma - 9.024 \cdot 10^{-6}\sigma^2 + 0.005351 \cdot \cos(2\pi(\chi - 0.4712))$$

$$H_0'^{\mathrm{midday}} = 74.74 - 0.02984 \cdot \sigma + 0.5705 \cdot \cos(2\pi(\chi - 0.4712) + \pi)$$



$$N_{e0}^{\mathrm{midday}}(\sigma,\chi,h) = 1.43 \cdot 10^{13} e^{-\beta^{\mathrm{midday}}(\sigma,\chi) H'^{\mathrm{midday}}(\sigma,\chi)} e^{[\beta^{\mathrm{midday}}(\sigma,\chi) - 0.15]h}$$

We consider:
- Two signals;
- Periods before and during influence of a solar X-ray flare;
- Variations of the amplitude and phase from their values before perturbation induced by a solar X-ray flare.

Results - Daytime periods

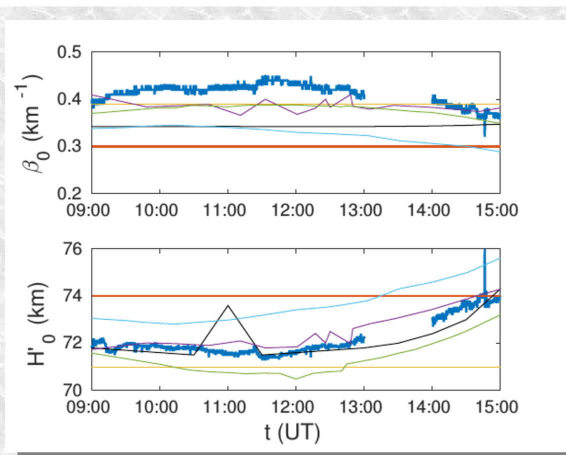
We consider:
- One signal;
- The quiet daytime period far from the sunrise and sunset due to approximation of horizontally uniform ionosphere;
- Variations of the amplitude and phase from their values at the midday.

Recorded values

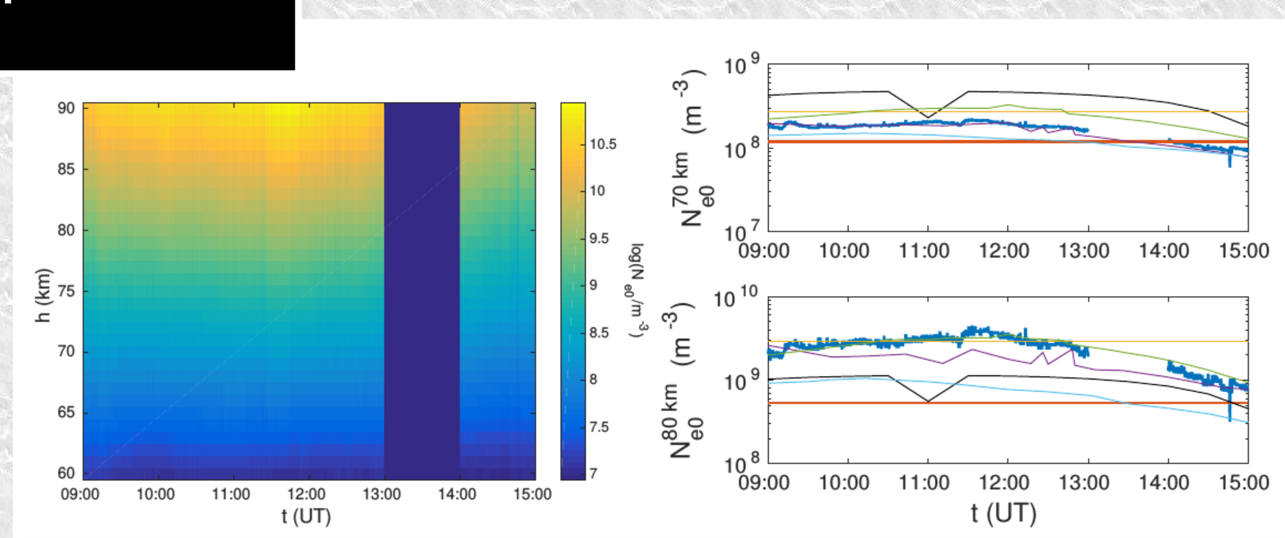
$$A - A^{\mathrm{midday}} = A_{\mathrm{mod}} - A_{\mathrm{mod}}^{\mathrm{midday}}$$

$$P - P^{\mathrm{midday}} = P_{\mathrm{mod}} - P_{\mathrm{mod}}^{\mathrm{midday}}.$$

Values obtained in the first part of model



6 September 2014



QIonDR; LWPC default [22]; IRI [52]; Thomson et al., 2005 [27]; Han et al., 2011 [33]; McRae and Thomson, 2000 [35]; Thomson et al., 2017 [53]

Summary

- QionDR model provides a numerical tool for modelling the daytime Wait's parameters over the middle and low latitudes depending on location, sunspot number and day of year.
- Analytical expressions valid over a part of Europe for midday Wait's parameters are developed in this study.

[1] *Nina et al., Remote Sens. 2021, 13, 483.*
[2] *Ferguson, J.A. Space and Naval Warfare Systems Center: San Diego, CA, USA, 1998.*
[3] *Wait, J.R.; Spies, K.P. NBS Technical Note: Boulder, CO, USA, 1964.*