Sporadic E- and F-layers coupling

Kamil Yusupov*(1), Maksim Tolstikov (2), Alexey Podlesnyi (2), Ruslan Sherstyukov (1), Anvar Safiullin (1), Arthur Bakirov(1)

(1) Kazan Federal University, Russian Federation, 18 Kremlyovskaya street
Kazan 420008, https://kpfu.ru
(2) Institute of Solar-Terrestrial Physics SB RAS, Irkutsk, Russian Federation

Abstract

A long-term experiment is carrying out at the Kazan Federal University to observe the fast parameters of the layers of the ionosphere in the one-minute mode of sounding of the ionosphere by ionosonde. This paper describes the algorithm for determining the critical frequency of ionosphere layers for such a large data flow. Based on the processing of this data, a correlation is found between the parameters of the E- and F-layers.

1. Introduction

The currently known theoretical and empirical ionospheric models sufficiently well describe quite ionosphere, its dependence on magnetic disturbance and solar activity, as well as the average longitude, latitude, diurnal and seasonal variations. These models have great practical value for the selection of optimal radio communication conditions, estimation of the situation in the surface plasma, calculation of specific radio paths, etc. Unfortunately, the value of electron concentration given by models can differ from the real one by tens of percent. The improvement of models requires the identification and consideration of new factors that have a significant effect on variations in the electron concentration. Therefore, the study of little-known short-period variations of the critical frequency and the virtual height of the sporadic E layer, as well as the coupling of these variations with the variations in the F parameters of the ionosphere traveling ionospheric disturbances and internal gravity waves (TID and IGW) is an important task. This study will help to collect more fundamental information about Es layers, in particular, it will help to clarify the form of the electron density profile of the Es layer and will allow to clarify the parameters influencing to the Es layer characteristics, which will enable to improving the Earth's ionosphere model and sporadic layer E

The ionosphere of the Earth is the research object of many scientific groups with the help of various methods of observation [1-10]. The main ionospheric observation methods are satellite, radar, optical, acoustic, laser, etc. Now, such interest is caused by the high variability of the ionosphere, which is a reaction to a large number events taking place in the depths either on the surface of the Earth and in space, including human influence. Such reactions or responses of the ionosphere to disturbances are important to know and to explore. For example, special scientific companies with an increased ionospheric time resolution are conducted in which new types of transient layers in the E-region of the ionosphere are found [11-14]. These layers are substantially different from the Es layers, and the meteoric causes of their origin have been established. By injecting aerosols at ionospheric heights with the help of rocket technology with simultaneous observations on radars and ionosondes in the rapid run mode the formation of additional layers generated by aerosol emission is observed. In recent decades, the emergence of a new optical technology measurements makes it possible to study the structure and dynamics of the upper layers of the atmosphere and the ionosphere at large horizontal scales with the help of spectrometers and ASI, which allows observing the passage of IGW and determining their propagation directions/periods, as well as the connection with moving ionospheric disturbances in the F-region. Studies of rapid oscillations of the sporadic E layer and their association with TID/IGW on a large time intervals were not carried out because they are possible only in the ionospheric sounding mode at a rate of 1 ionogram per minute, which is inaccessible for most ionospheric sounding instruments. Thus in the next section the used experimental equipment were described.

2. Experimental equipment

To study the Es-layer parameters from February 2010 the measurements were carried out with the Cyclone ionosonde at Kazan, Russia. The updating of the Cyclone ionosonde control system makes it possible to ionosphere sounding in the rapid mode, which is necessary for the investigation of small known rapidly changing processes in the ionosphere. In view of the fact that the rate of ionosphere variability can vary over a wide range, a mode with a maximum frequency of ionogram sampling for our ionosonde (1 ionogram per minute or 1440 ionograms per day) was established. The sounding frequency ran from 1,5 to 9 MHz in 20 s (the maximum sounding frequency was slightly changed depending on the time of year), the frequency range was 400 frequencies with equal steps, the repetition rate of pulses was 20 Hz, the duration of the sounding pulse was 70 μs. The antenna system represented two crossed delta antennas (one was for emitting, another for receiving).
3. Data treatment

To study variations of critical frequencies with a minute steps of ionograms the ionosphere summary maps (A-maps) were used. These maps are constructed by choosing the maximum amplitude of reflection from the ionospheric layers from each ionogram for the whole day. Next, for the critical frequency detection, an interactive selection approach was used, when the computer mouse is moved along the visible contours of the critical frequency of the ionospheric layers at A-maps. The written program, which makes a small digital filtering of these curves and saves to the matrix with the date, time and frequency values. This format is convenient for stream processing. An example of A-maps for E- and F-regions with critical frequencies of the extraordinary component highlighted on them is shown in Figures 1 and 2, respectively for July 6 2014. The critical frequency of an ordinary component is easy to be found by subtracting half of the electron gyrofrequency from these curves.

![Figure 1. Example of A-map for E-region with critical frequencies of F- and E-layers.](image1)

![Figure 2. Example of A-map for F-region with critical frequencies of F- and Es-layers.](image2)

4. Results

Figure 3 separately shows the previous curves of critical frequencies.

![Figure 3. Example f-plot for E-, Es- and F-layers with 1 minutes steps (arrows marks the times when simultaneously fEs increase and f0F2 decrease).](image3)

There are lot of TIDs on (July 6 2014). From ~ 0 to 3 hours TIDs with periods dozens of minutes were observed both in the F and Es layers. From figure 3 one can see that these disturbances correlate well with each other. From ~ 3 to 7 hours TIDs with periods ~ 1 hour were observed in the Es layer. There were not TIDs with such periods in the F layer at this time. From ~ 7 to 9, short-period disturbances were again observed in the F and Es layers, but correlation between the disturbances is worse. From ~ 9 to 14 powerful TIDs with periods of ~ 3 hours were observed in the Es layer causing partial screening of F2 layer. From 14 to 21 TIDs with periods from ~ 10 minutes to ~ 1.5 hours were observed in the Es and F layers. From ~ 21 to 22 powerful disturbances were again observed in the Es layer. So it is shown that it is possible to separate TIDs by using A-maps. In future works, we plane to obtain TIDs parameters(first of all, the apparent vertical velocity) from A and H-maps, and to observe TIDs propagation from the Es to the F2 layer.

5. Conclusions

An algorithm was developed to accurately determine the critical frequencies of the layers of the ionosphere with minute time resolution based on A-maps. Based on the analysis of the selected day data, a correlation is observed in the variation of the critical frequencies Es-layer with F-layer. It is planned to further study such a correlation over large time intervals.

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7. References


