COMPARISON OF THE ELECTRON DENSITY PROFILES MEASURED WITH THE INCOHERENT SCATTER RADAR, DIGISONDE DPS-4 AND CHIRP-IONOSONDE

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ABSTRACT

The paper is devoted to the comparison of the electron density obtained by the incoherent scatter radar, Digisonde and chirp-ionosonde. The main discrepancies can be explained by influence of ionospheric irregularities of different scales. During the morning hours the strong electron density gradients result that the ionosondes give the overestimated values in comparison with the incoherent scatter radar. The electron density disturbances obtained by the different instruments may have a correlated and uncorrelated nature. Uncorrelated disturbances are associated with intensive ionospheric irregularities of scales less or equal to 100 km. Correlated disturbances are due to ionospheric irregularities of scales considerably greater then 100 km.

INTRODUCTION

The electron density measurements with the three closely spaced radio technical instruments enable us both to perform mutual calibration of the instruments and to explore the capabilities which cannot be realized with each of the instruments by itself. The radio instrument complex of the Institute of Solar-Terrestrial Physics includes the incoherent scatter radar (ISR) [1], Digisonde (DPS-4) [2] and chirp-ionosonde or frequency modulated continuous wave (FMCW) ionosonde [3]. The locations of the ISR, DPS-4 and FMCW transmitter and receiver are shown in Fig.1. In the figure we also show the FMCW radio path, the ground projection of ISR beam and horizontal sizes of ISR beam at various heights. The comparisons were carried out for October 30 - November 1, 2003 and for November 9-12, 2004. Both periods included strongest for last years magnetic storms.

The distinctive property of the Irkutsk ISR implies that the electron density profile is measured by the Faraday rotation method [1] and hence ISR has no need of calibration by ionosonde. The electron density profile reconstruction from the both ionosondes data was carried out by the Reinisch and Huang method [4] with the extrapolation above a peak height by the method [5].

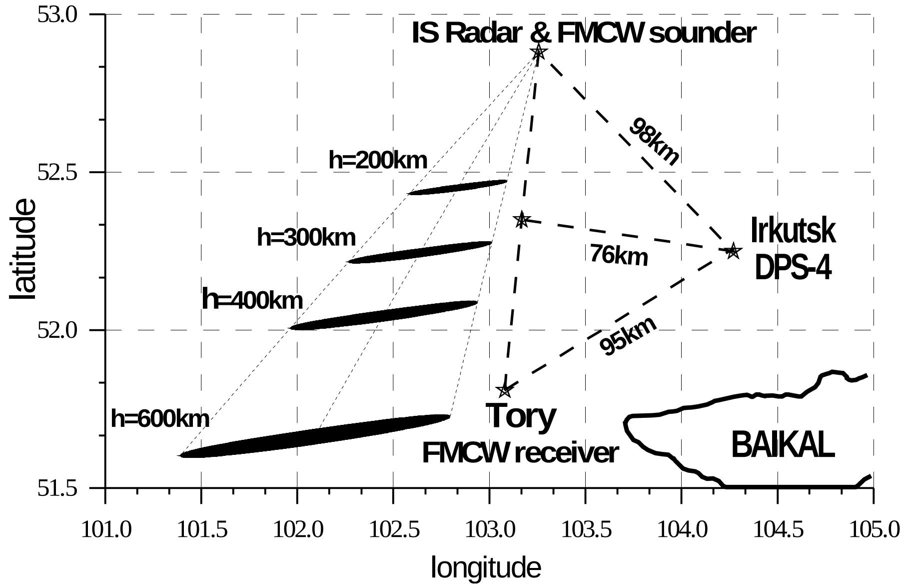

Fig.1 The locations of the ISR, DPS-4 and FMCW.

The comparison technique consisted in separate comparison of slow *Ne(z, t)* and fast *DNe(z, t)* electron density variations. The separation of variations into slow and fast ones was carried out by the filtering. The filter band was chosen so that the slow variations represented fluctuations with the periods $T > 4h.$, and fast variations were fluctuations in a range of the periods $1h. < T < 4h$. The comparison of slow variations has been performed for revealing the discrepancies in diurnal variations of the electron density. The comparison of fast variations has been conducted in an effort to extract an additional information about traveling ionospheric disturbances. Further we shall assume that function *Ne(z, t)* describes regular variations of the electron density and *DNe(z, t)* corresponds to disturbances.

COMPARISONS OF REGULAR ELECTRON DENSITY VARIATIONS

The comparisons of regular electron density variations obtained by the various instruments have revealed two main types of discrepancies. With the strong electron density gradients in the morning hours the DPS-4 gives the overestimated electron density values in comparison with the ISR. In the daytime the ISR gives higher values in comparison with the DPS-4 at heights below and above the peak height, i.e. ISR produces thicker profile. Both types of discrepancies are demonstrated in Fig. 2 where the regular electron density variations measured by ISR (solid line) and DPS-4 (dashed) on November 12, 2004 are shown. The distinction between the DPS-4 and ISR data in the morning hours can be explained as follows: the strong spatial electron density gradients deflect the HF radiowave path from the vertical in the direction of increasing density, as a result the ionosonde receives echoes from the east regions and gives the overestimated electron density values. The fact that the ISR produces thicker profile may be connected with several reasons. On the one hand there is a number of the factors by which the ISR produces the height-averaged profile. Among these are the finite duration of the radiated pulse and a rather large horizontal size of the ISR beam along with a beam inclination of 16° from a vertical. On the other hand the absence of ionogram traces at low frequencies because of absorption or blanketing by Es-layer may cause the profile thickness to decrease. At the moment it is not clear what instrument distorts the profile to a greater extent.

The regular electron density variations observable by the chirp-ionosonde are much closer to the variations measured by the DPS-4 than to the ISR data. Accordingly the discrepancies between the chirp-ionosonde and ISR replicate the main features of discrepancies between the DPS-4 and ISR.

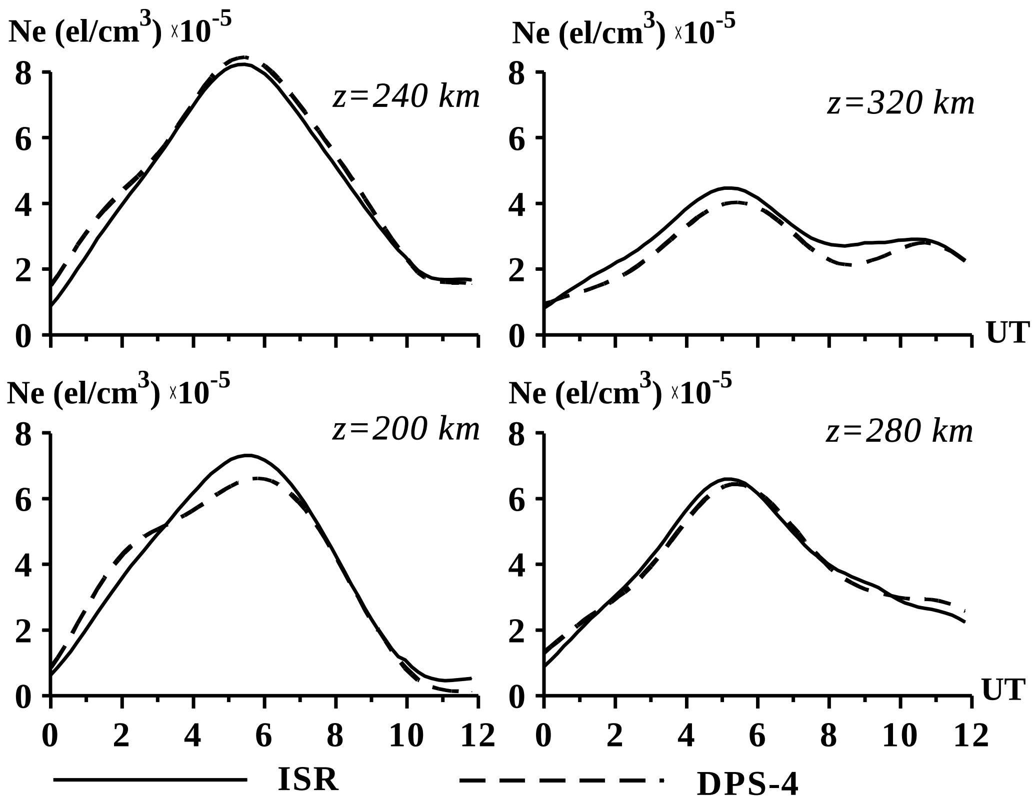

Fig.2 The regular electron density variations measured by ISR and DPS-4. November 12, 2004. LT=UT+7.

COMPARISONS OF ELECTRON DENSITY DISTURBANCES

The electron density disturbances obtained by the different instruments may be separated into two types: correlated and uncorrelated disturbances. The both types were clearly observed on November 9, 2004. The electron density disturbances measured by the ISR (solid line) and DPS-4 (dashed) on this day are shown in a Fig. 3. From 0 to 5 UT there is no correlation between the ISR and DPS-4 disturbances. At this time the DPS-4 recorded complex ionograms with oblique or spread echo traces. The good correlation between the disturbances is seen from ~ 6 UT, when the ISR and DPS-4 data are about the same fluctuations shifted in time. At this time the DPS-4 recorded the relatively simple ionograms.

Correlated disturbances are due to ionospheric irregularities of scales considerably greater then 100 km, and to the traveling ionospheric disturbances caused by acoustic-gravity waves in particular. Accordingly the observation of such disturbances by the various instruments can be used for measuring disturbance characteristics, like the velocity and motion direction.

Most likely the uncorrelated disturbances are due to intensive ionospheric irregularities of scales less than or equal to 100 km. The difficulties in measuring disturbance characteristics are primarily associated with the difficulties in interpreting complex ionograms in the presence of oblique or spread echo traces.

Of special interest is the strong positive electron density disturbance observed from 6:45 UT on November 10, 2004 during the main phase of the strong magnetic storm. The disturbances obtained by the ISR (solid line) and DPS-4 (dashed) on this day are shown in a Fig. 4. Both instruments show some identical disturbance properties, such as the duration, the peak time and increase of disturbance amplitude with height. All this assigns the disturbance to the correlated type. The main discrepancy between the disturbances consists in higher disturbance amplitude observed by the ISR. Probably this discrepancy is connected with the fact that the DPS-4 ionogram height range was limited by 730 km. One can see from Fig. 4 that the disturbance shape noticeably varies with the height, suggesting that there is an interference of two disturbances.

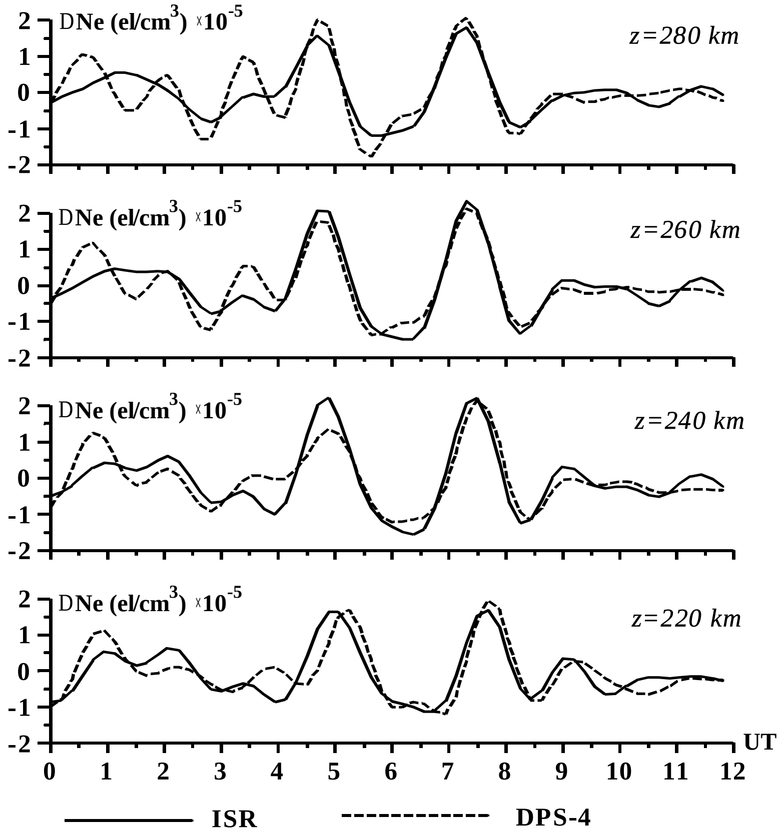

Fig.3 The electron density disturbances measured by ISR and DPS-4. November 9, 2004. LT=UT+7.

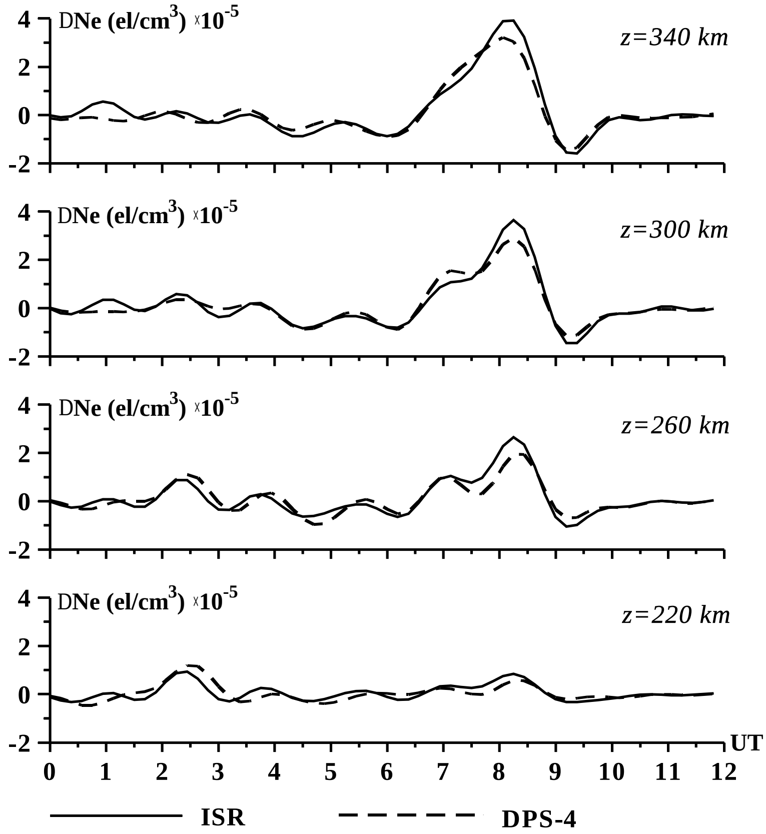

Fig.4 The electron density disturbances measured by ISR and DPS-4. November 10, 2004. LT=UT+7.

CONCLUSION

The electron density measurements with the three closely spaced radio technical instruments allowed us to reveal the listed below types of discrepancies. With the strong electron density gradients in the morning hours the ionosondes give the overestimated electron density values in comparison with the ISR. The ISR produces thicker profile in comparison with the ionosonde data. The electron density disturbances obtained by the different instruments may have a correlated and uncorrelated nature. The observation of the correlated disturbances by the various instruments can be used for measuring the disturbance velocity and motion direction.

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