Ionospheric drift measurements in heights 90-150 km during sporadic E-layer occurrence using Digisonde DPS-4

Kouba D.[1,2], **Šauli P.**[1], **Boška J.**[1], **Santolík O.**[1,2]

[1] Institute of Atmospheric Physics, Academy of Sciences of the Czech Republic, Bocni II 1401, 141 31 Prague 4, Czech Republic, tel. +420272016066 fax. +420272763745, e-mails: kouba@ufa.cas.cz, pkn@ufa.cas.cz, boska@ufa.cas.cz, ondrej.santolik@mff.cuni.cz

[2] Department of Surface and Plasma Science, Faculty of Mathematics and Physics, Charles University, V Holešovičkách 2, 180 00 Prague 8 - Liben Czech Republic, Prague

Abstract

Regular measurement of plasma motion brings new important information about the state of the ionosphere. Our contribution is focused on the ionospheric plasma motion at the height range 90 km - 150 km (corresponding to the E-region ionosphere). Study involves observations from midlatitude ionospheric station Pruhonice (50N, 14.6E) using DPS4 equipment during period of low solar activity (2006-2007).

Raw data are manually checked and controlled using skymap points selection method [1] consisting of robust reflection height range selection, setting limits on the Doppler frequency shift, and restriction of the echo arrival angle. During summer periods of 2006 and 2007 we performed special campaigns of 'Es drift' measurement. Together with standard E measurement (2-2.6 MHz) we recorded plasma motion each 15 minutes also in a higher frequency window (3.2 - 4.7 MHz).

Our results show different behavior of plasma motion in the 'E' and 'Es' layers. This fact confirms drift velocity height dependence in the interval 90 - 150 km and calls for careful interpretation of the E-drift during presence of Es layer.

1. Introduction

Since January 2004 new Digisonde with four cross-loop receiving antennas (Digital Portable Sounder 4, DPS4) provides routine ionospheric measurements in the Průhonice Observatory. Digisonde DPS4 records an ionogram every 15 minutes, except special campaigns of higher sampling rate. Ionogram autoscaling process “ARTIST” automatically finds the F-region critical frequency foF2, from which convenient sounding frequencies are calculated for F-region drift measurements [3] (it follows routinely 5 minutes after the ionogram sounding). Therefore, sounding frequencies vary from measurement to measurement according to critical frequency foF2.

Since May 2005, the Pruhonice Digisonde also measures E-region drifts every 15 minutes (9 minutes after the ionogram sounding), using four fixed frequencies between 2.0 and 2.6 MHz. On the contrary to the autodrift setting, E region sounding frequencies do not depend on critical frequency: they are set and fixed for all the sounding campaign.

Drift measurement does not make sense when critical frequency falls under the sounding frequency of a given layer, hence E-region drift measurement at frequencies 2.0 - 2.6 MHz operates only during day-time. However, measurement was extended to night-time due to occurrence of the sporadic E layer. Thanks to this extension we have begun to concentrate also on the dynamics of Es layer. Regarding to frequent occurrence of Es layer in midlatitudes during summer the following question can arise: Are the drift measurements for E-layer affected by occurrence of Es layer?

During summer 2006 a special campaign for monitoring drifts in Es layer was performed. Drift-measurement on a higher sounding-frequency window 3.2-4.7 MHz was run every 15 minutes in addition to the standard E-region drift measurement.

Critical frequency of the E-layer exceeded 3.2 MHz above Průhonice observatory during campaign period only seldom, around diurnal maximum of foE. Limits of sounding-frequency windows were chosen on the basis of foE behavior pattern in midlatitudes during summer 2005. Therefore, occurrence of Es layer during day-time drift measurement in the lower frequency window in most cases corresponds to E-layer echoes on the ionogram.

Within occurrences of the Es layer with the critical frequency above 3.2 MHz successful measurements corresponding to Es echoes on the ionogram (‘Es drift’) were found.

2. Two sounding frequency windows regimes

Use of two sounding-frequency windows setting in dependence on actual foE and foEs values leads to the following measurement regimes:

- without Es occurrence
  - A) foE < 2 MHz – no successful drift measurement for heights 90-150 km; typical night situation without Es (winter)
  - B) 2 MHz ≤ foE < 3.2 MHz – successful E drift measurement in the lower sounding-frequency window; typical day-time without Es
  - C) foE ≥ 3.2 MHz – successful measurement of E-drift on both frequency windows; day-time with highest foE
- with Es occurrence
  - foE < 2 MHz
    - D) 2MHz ≤ foEs < 3.2 MHz – successful ‘Es drift’ measurement in the lower frequency window; day-time situation with inexpressive Es occurrence
    - E) foEs ≥ 3.2 MHz - successful ‘Es drift’ measurement in both frequency windows; typical night-time situation with Es occurrence
  - 2 MHz ≤ foE < 3.2 MHz
    - F) 2MHz < foEs < 2.6 MHz - E drift measurement in the lower frequency window can be affected by both E and Es reflections; no successful drift measurement in the higher frequency window
    - G) 2.6MHz < foEs < 3.2 MHz - successful E drift measurement in the lower frequency window; day-time situation with inexpressive Es occurrence
    - H) foEs ≥ 3.2 MHz - successful E drift measurement in the lower frequency window and successful ‘Es’ measurement in the higher frequency window; typical day-time situation with Es occurrence
  - I) foE ≥ 3.2 MHz - successful E drift measurement in the lower frequency window, measurement in the higher frequency window can be affected by both E and Es reflections.

Each drift measurement is represented by a unique skymap. According to the skymap points selection method [1] we select appropriate points from these skymaps in order to calculate correct drift velocity estimates using the DDA method [2]. We thus obtain corrected drift velocity history graphs.

3. One-day drift measurement

An example of one-day velocity plot in the presence of Es layer is shown in Figure 1. For Jun 25 2006 there are measurements for the lower sounding-frequency window plotted by solid dots and for the higher sounding-frequency window plotted by light dots. Evolution of critical frequencies foE and foEs during Jun 25 2006 is represented in Figure 2. Each measurement of foE and foEs values corresponds to specific measurement regime described above. Time intervals mark availability of particular measurement regimes. Sporadic E-layer occurs during whole studied day.

Critical frequency of E-layer gets inside the lower sounding-frequency window (exceeds 2.0 MHz) shortly after 4 a.m. and falls under 2.0 MHz around 6 p.m. Therefore, before 4 a.m. and after 6 p.m. drifts are measured in ‘night-regimes’ D and E (see above); drift in the Es layer is respectively registered only in the lower frequency window or in both frequency windows. Measurement regime H (see above) occurs most of the time between 4 a.m. and 6 p.m. In the time interval between 11 a.m. and 13 p.m. there can be measurements in the higher sounding-frequency window ‘mixture’ between E and Es drifts. In that time interval it is necessary to be careful in interpretation of drifts measured in the higher frequency window.

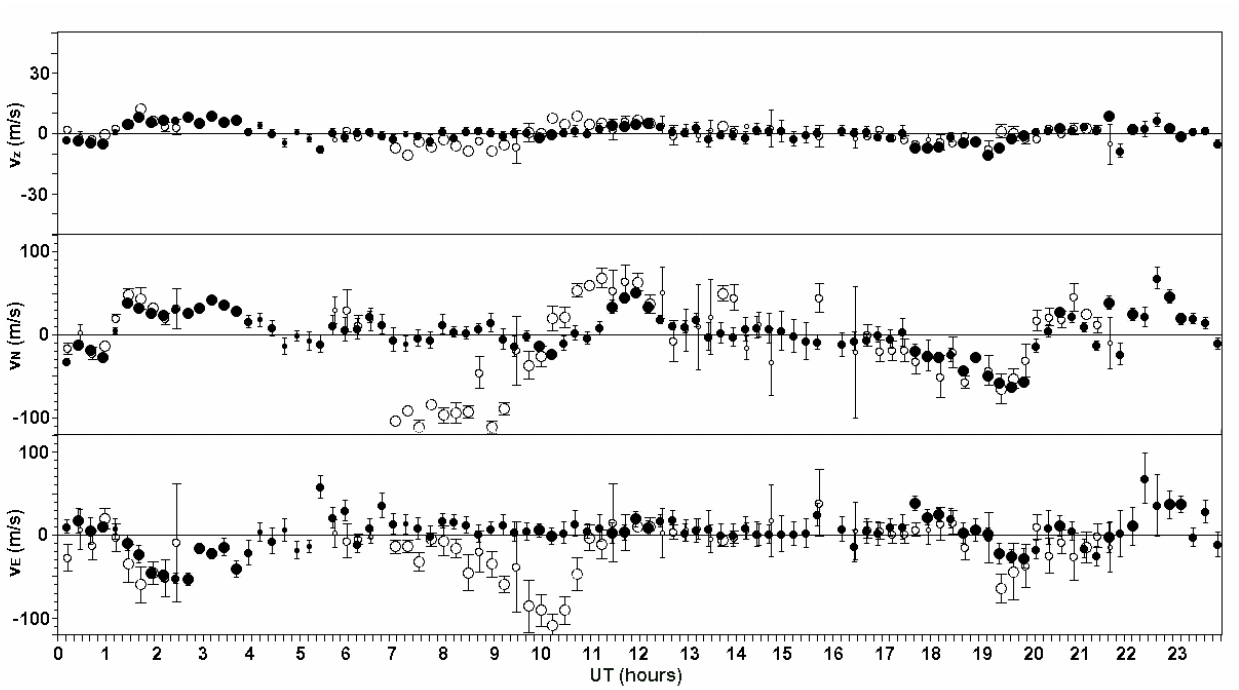

Figure 1. One-day E-region drift velocity components for Jun 25, 2006. Measurements for the lower sounding-frequency window (2-2.6 MHz) are plotted by solid dots and for higher sounding-frequency window (3.2-4.5 MHz) are plotted by light dots. Three levels of dot magnitude indicate quality of measurement.

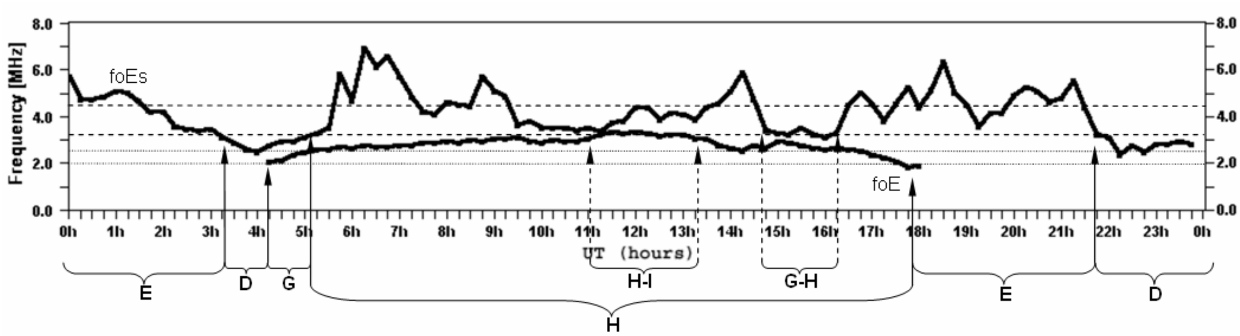

Figure 2. Critical frequencies foE and foEs for Jun 25, 2006. Particular measurement regimes indicate characters below plot.

In the time interval 0-2 a.m. good-quality Es skymaps are registered in both sounding-frequency windows. Es drift velocity has practically the same behaviour for both frequency windows measurements. After 2 a.m. the critical frequency foEs is close to 3.2 MHz and subsequently it falls below 3.2 MHz, thereupon correct measurements are only those for the lower frequency window. One can see an interesting situation between 6 a.m. and 11 a.m. – drift measurements work in regime H, the lower frequency window corresponds to E-drift measurements and higher frequency window corresponds to Es-drift. During that time interval there is a sufficient number of good-quality measurements for both frequency ranges. E and Es drift velocities show expressive differences in that time interval. Measurements demonstrate distinctively different dynamics of Es layer and the rest of the E-region height-interval.

Between 11 a.m. and 6 p.m., most skymaps are characteristic by a low number of reflection points and reflection points are cumulated in a small cloud for the higher frequency window. That leads to the poor quality of the estimated Es-drift velocity value in that time interval. After 6 p.m., there are enough good-quality measurements again for both frequency windows. All results describe Es-drifts in this case and show a consistent behaviour.

4. Discussion

Our results show height dependence of drift velocity in the E-region interval, especially in the presence of the Es layer. During summers 2006 and 2007 we performed special drift measurements campaign. For E-region we recorded plasma motion each 15 minutes on two frequency windows.

Analysis of the drift motion in two different sounding-frequency windows shows consistent behaviour during night time (Fig.1) while during day time plasma motion can be significantly different in each window (Fig.1). However, significant differences can be found in quality of measurements.

Proposed two frequency-window E-region drift measurement method enables us to successfully register drifts in both E and Es layers. During all the day we used proposed unchanging two frequency-window setup. Diurnal dependence of foE and foEs values implicate different measurement regimes during the day.

Even though the resulting skymaps are not always of good-quality, such routine measurement regimes represent an important source of information about the dynamics of the E region ionosphere and bring new pieces of information about sporadic E layer formation and its behaviour. Differences of the plasma motion confirm different dynamics of E and Es layers.

We also demonstrate that whenever the Es layer occurs it is necessary to be careful in interpretation of the traditional single-sounding-frequency-window E-drift measurement.

5. Acknowledgements

This work was supported by the Grant Agency of the Academy o Sciences of the Czech Republic (project IAA300420704), by the Czech Grant Agency, project No. 205/06/1267 and European Union project COST 296 (MIERS).

6. References

1. Kouba, D., J. Boška, I. A. Galkin, O. Santolík, and P. Šauli, Ionospheric drift measurements: Skymap points selection, *Radio Sci.*, *43*, 2008.

2. Reinisch, B.W., J.L. Scali and D.M. Haines, Ionospheric drift measurements with ionosondes, *Annali di Geofisica, 41*(5-6), 695-70, 1998.

3. Reinisch, B.W., X. Huang, I.A. Galkin, V. Paznukhov, A. Kozlov, Recent advances in real-time analysis of ionogram and ionospheric drift measurements with Digisondes, *J. Atmos. Sol. Terr. Phys., 67,* 1054-1062*,* 2005.