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Ionospheric vertical drift response at a mid-latitude station

Daniel Kouba *, Petra Koucká Knížová

Institute of Atmospheric Physics CAS, Bocni II 1401, 141 31 Prague, Czech Republic

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Abstract

Vertical plasma drift data measured at a mid-latitude ionospheric station Pruhonice (50.0°N, 14.6°E) were collected and analysed for the year 2006, a year of low solar and geomagnetic activity. Hence these data provide insight into the drift behaviour during quiet conditions. The following typical diurnal trend is evident: a significant decay to negative values (downward peak) at dawn; generally less pronounced downward peak at dusk hours. Magnitude of the downward drift varies during the year. Typically it reaches values about 20 m s^{-1} at dawn hours and 10 m s^{-1} at dusk hours. Maximum dawn magnitude of about 40 m s^{-1} has been detected in August. During daytime the vertical drifts increases from the initial small downward drifts to zero drift around noon and to small upward drifts in the afternoon. Night-time drift values display large variability around a near zero vertical drift average. There is a significant trend to larger downward drift values near dawn and a less pronounced decrease of the afternoon upward vertical drifts near sunset. Two regular downward peaks of the drift associated with the dawn and dusk are general characteristics of the analysed data throughout the year 2006. Their seasonal course corresponds to the seasonal course of the sunrise and sunset. The duration of prevailing negative drift velocities forming these peaks and thus the influence of the dawn/dusk on the drift velocity is mostly 1.5–3 h. The dawn effect on vertical drift tends to be larger than the effect of the dusk. The observed magnitude of the sunrise and sunset peaks show significant annual course. The highest variability of the magnitude is seen during winter. High variability is detected till March equinox and again after September equinox. Around solstice, both peaks reaches lowest values. After that, the magnitudes of the drift velocity increase smoothly till maxima in summer (August). The vertical drift velocity course is smooth between June solstice and September equinox. In general, the detected values of the observed vertical drift are of lower magnitudes compare to low latitudes. Drift data in midlatitudes seems to be more influenced by the atmospheric waves than data in lower latitudes.

Keywords: Vertical plasma drift; Digisonde; Mid-latitude ionosphere; F-layer; Daily pattern

1. Introduction

Nowadays there are many ionospheric stations equipped with various ionosondes around the world. There are several models operating (Digisondes, IPS ionosondes, Canadian Advanced Digital Ionosondes, dynasondes), however practically Digisondes only measure the drifts on a regular base. A classical ionosonde uses the vertical ionospheric sounding to produce ionograms. The vertical ionospheric sounding provides the information about the profile of electron concentration. In general the ionospheric plasma is in motion, driven by electric fields and neutral winds. Information about the magnitude of these movements can be obtained using the direct drift measurements provided by modern digital ionosondes.

The transmitted signal illuminates a large area of the ionosphere due to the antenna radiation pattern. Receiving antennas detect signal reflected from the ionosphere. For a perfectly smooth, vertically stratified ionosphere only one such location exists, responsible for a single vertical echo.

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* Corresponding author.
E-mail addresses: kouba@ufa.cas.cz (D. Kouba), pkn@ufa.cas.cz (P. Koucká Knížová).

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However, large number of oblique echoes is usually detected. The non-vertical echoes occur due to ionospheric tilts near the solar terminator, modulations by atmospheric gravity waves, irregularities generated by plasma instabilities and other ionospheric phenomena. Detection of echoes from oblique directions is crucial for drift measurements.

Spectral analysis is applied to the signal reflected from the ionosphere to distinguish individual echoes with different Doppler frequency shifts. For individual echoes heights of reflections, horizontal locations of reflection points in the ionosphere, values of Doppler shift, and signal amplitudes on receiving antennas are identified. Location of the reflection points can be graphically displayed in so called SKYmap (Reinisch et al., 2005).

The technique for drift velocity determination is commonly referred as the “Digisonde Drift Analysis” (DDA method) and the resulting velocity is called the “drift velocity” (Reinisch et al., 1998). The DDA method is implemented in the software tool “Drift Explorer” (Kozlov and Paznukhov, 2008) commonly used by Digisonde users. The automatic data processing software is distributed with the Digisondes for plotting the real-time SKYmaps and automatic drift velocity computing. Automatically scaled data are available through the Digisonde web pages and DriftBase (Reinisch and Galkin, 2011).

For a given month Altadill et al. (2007) obtained daily pattern of the vertical velocity component by computing the monthly median values for mid-latitudinal station Ebro. Their study indicates daytime values usually close to zero with low variability. Night-time values display larger variability. The most distinct and systematic feature occurs after sunrise when vertical velocity decreases rapidly to a negative value of about -20 to -50 m/s.

Belehaki et al. (2006) obtained the daily drift pattern for mid-latitudinal station Athens during quiet geomagnetic conditions. They detected a daily pattern in horizontal components of drift velocity vector. However the vertical component tends to present only a weak diurnal pattern with small amplitude.

It is possible to determine the complete drift velocity vector using the described Digisonde drift measurements. When we focus on the vertical component of the drift velocity only, there are several other possibilities. Using multi-frequency HF Doppler radar observation is another possibility for direct measurement of the drift velocity vertical component (Prabhakaran Nayar et al., 2009; Mathew, 2010). The advantage of this technique in comparison with multifunctional Digisonde is usually the better time resolution.

Mathew (2010) deal with pre-sunrise and post-sunset characteristics of equatorial vertical plasma drift measured with multi-frequency HF Doppler radar. They observed the post-sunset enhancement and quasi-periodic fluctuations with periodicities 20–32 min. during post-sunset period. The plasma drift during pre-sunrise period shows enhancement prior to the ground sunrise followed by downward excursion.

Incoherent scatter radar (ISR) is another instrument usable for direct measurement of ionospheric drifts (Woodman and Hagfors, 1969). Jicamarca ISR can continuously observe vertical and zonal components of ion velocities. Based on the long term Jicamarca ISR measurements, a model of drift velocity was developed (Scherliess and Fejer, 1999). This is a widely used model for the equatorial region. During the day the upward direction is dominant and during night the downward direction of vertical drift in equatorial F region prevails in the quiet conditions (Fejer et al., 1991). There are also other models obtained using different measurements, the list can be found in Adeniyi et al. (2014).

The height-resolution measurement of coherently scatter echoes occurring during daytime hours at around 150 km altitude is the alternative to monitoring the equatorial vertical drifts by ISR (Kudeki and Fawcett, 1993).

The experiment using ROCSAT-1 cannot be omitted in the list of the direct methods used to obtain information on vertical ionospheric drift (Yeh et al., 1999; Fejer et al., 2008).

The indirect estimation based on the temporal evolution of the measured ionospheric characteristics is also often used for the calculation of the vertical drift component. The vertical velocity is estimated according to the change of characteristics, usually reflection frequency or corresponding electron concentration, scaled from the classical quarter-hour-ionograms.

The cadence of ionogram measurements (typically 15 min) can be problematic. The drift velocity is calculated for each time interval between ionogram measurements. This assumes that the change of drift velocity will be slower than the time difference between the individual ionograms. It may be satisfying for quiet conditions but there are many detectable processes which are much faster volatile – geomagnetic storms, TID, etc. The advantage of this method is that it can be used for historical data or classical ionosondes which are not able to provide direct drift measurements.

For example the value of $(\mathrm{d}h'F/\mathrm{d}t)$ is then called a vertical drift velocity (Batista et al., 1986; Saranya, 2014). This method is often limited to the measurements in the evening hours when the F-layer height is over 300 km (Batista et al., 1996; Subbarao, 1994). Bittencourt and Abdu (1981) found that for special time periods during sunset and evening hours, F-region exceed a threshold height 300 km, the apparent vertical displacement velocity of the F-region, inferred from ionosonde measurements, correspond to vertical $\mathbf{E} \times \mathbf{B}$ plasma drift velocity determined by incoherent backscatter radar measurements in the F region. Below a threshold the recombination processes affect significantly the plasma motion. Good agreement between Digisonde and incoherent scatter radar drift measurements during sunset and evening hours are reported by Bertoni et al. (2006). Additionally they found the correspondence during post-midnight hours (between 02 and 03 LT) and sunrise