Comparison of different calculation techniques of vertical velocity component of F-layer drifts

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Abstract

It is presented in this work a study of vertical drift of ionospheric plasma with different techniques. We have used data sets registered by a DPS-4 and Incoherent Scatter Radar (ISR) both operating at Jicamarca (12°S; 77°W), Peru. Comparisons of three different techniques to calculate vertical drifts and ISR drift measurements as well are presented. Velocities are calculated with dhF/dt (using real heights for 4MHz from ionograms), $dhF_{0.80}/dt$ (frequency of 80% of foF2) and line-of-sight method (V_{los}).

Introduction

Doppler interferometry has been widely used by several sorts of instruments to make reflection source location and velocity measurements. Some digital ionosondes have this capability. We have been using Digisondes DGS-256 and DPS-4 to make soundings in a routinely basis.

Digisondes work with a receiver array of four antennas, which has the format of an equilateral triangle with one of the antennas located at its center.

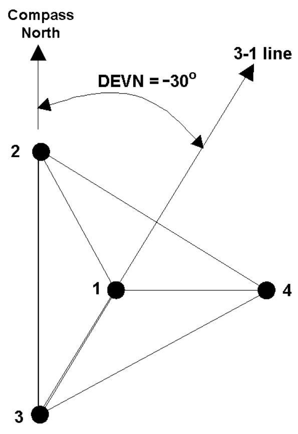

Fig. 1 – DPS-4 receiver antenna configuration array.

Source: Galkin and Paznukhov, 2002.

Antenna configuration varies from station to station. It depends on the location and relation with the geomagnetic field – that is, if site is located at high, middle or low (geomagnetic) latitudes.

Jicamarca receiver antenna array has the same configuration of the schematics showed in the Figure 1.

DDA is a package of applicative programs to evaluate calculations based on Doppler interferometry (Bibl *et alii*, 1975; Dozois, 1983; Bullett, 1994, Scali *et alii*, 1995, Bertoni, 1998) and generates the skymaps (DDAS program) and velocity vectors (DDAV program). Skymaps are diagrams with location of reflection source points in a radial format.

So it is important to properly set the antenna coordinates in order to get correct readings of ionograms, drift measurements and skymaps.

We have used, at this work, time derivative or real heights (dhF/dt) to calculate vertical velocities for a given sounding frequency. We show dh(4)/dt that is the real height of 4MHz. Besides, we introduce the method of $dhF_{0.80}/dt$ which is the derivative of real height of frequencies of 80% of foF2 (electronic density F2-layer peak frequency).

Also is showed V_{los} method, which uses DDAS program to make reflection source position vector calculations and Doppler shift in frequency. Output files have important part of the information we have used in the present computational program at this work.

One of the efforts to study vertical drifts with this method is to eliminate the horizontal velocity component contributions. In the other techniques (dhF/dt, $dhF_{0.80}/dt$) reflection sources may be off overhead and consequently present horizontal velocity component contributions. Setting small angles such as 3° of zenith, we can avoid it.

Method

Line-of-sight velocity is related to frequency Doppler shift according to the following expression:

$$V_{los} = -\frac{c}{2}\frac{\Delta f}{f} \qquad (1)$$

where *c*, Δf and *f* represent, respectively, light speed, frequency Doppler shift and, transmitted pulse frequency. Doppler shift is calculated through:

Δf = Spectral Doppler Line $\times$ Spectral Resolution

Spectral Doppler line is taken from files generated by DDA fortran code called DDAS (mentioned above) which locates reflection sources. Spectral resolution, by its turn, is calculated by the following expression:

$$df = \frac{1}{CIT} \qquad (2)$$

Where *CIT* stands for Coherent Integration Time and in the case of DPS-4 is given by:

CIT = (Number of Spectral Lines × Waveform × No. Antennas × Polarization × Multiplexed Frequencies) / (Pulse Repetition Rate / *X*)

Number of spectral lines is equal to 2^N, where N is one of the sounding parameters, usually equal to 6 or 7 (for that instrument). Waveform, as the name suggests, is related to the wave code used for soundings and usually is equal to 1 (complementary code) (Stelmash *et alii*, 2000), in this condition the correction factor is $X = 2$. Number of antennas as well as Polarization is equal to 1 for DPS-4. And pulse repetition rates may be equal to 50, 100 or 200Hz.

Vertical velocity by dhF/dt is calculated by the difference between real heights of a given frequency in two successive ionograms. And $dhF_{0.80}/dt$ is calculated based on real heights, which correspond to frequencies of 80% of foF2 along the day. That is, we take a value of real height, which corresponds to a frequency of 80% of foF2, for a given time, and the real height of the same frequency in 5 successive ionograms. So it is used more accurate derivative method to get the time derivative of those sets of heights.

Examples

As a illustrating example, let us consider $N = 7$, Waveform = 1, $X = 2$ and, Pulse Repetition Rate equal to 50Hz, then we have Number of Spectral Lines (2^7) equal to 128 – that means 64 lines for negative Doppler and other 64 for positive Doppler. *CIT* is equal to 20.48s. Consequently Spectral Resolution is 0.0488Hz. In this way is set a scale for Doppler frequency shift which extends from –3.125Hz to 3.125Hz. Multiplying the Spectral Resolution by the Spectral Line Number, we get the value of Doppler shift in frequency of the echo and, so, the line-of-sight velocity.

If the Number of Spectral Line is 20 we have a Doppler shift of 0.976Hz in the frequency. Now assuming a sounding frequency of 6MHz this reflection source moves with a velocity of $Vz \approx$-24.5m/s. Since positive velocities are upward and negative downward, it means that reflection source point is approaching the receiver antenna array.

Results

We have applied the techniques described above to a set of 3 days of December 2001, more specifically 10, 11 and 13. Unfortunately 12/Dec has no data available for the whole day.

Data are from Jicamarca Radio Observatory provided by CEDAR and University of Massachusetts Lowell Center for Atmospheric Research.

A Digisonde DPS-4 and the incoherent scatter radar (ISR) were operating simultaneously at that location. Possibility of comparison between measurements was interesting because ISR measures electromagnetic drift (**E** × **B**) and line-of-sight velocity is usually an apparent velocity of the plasma.

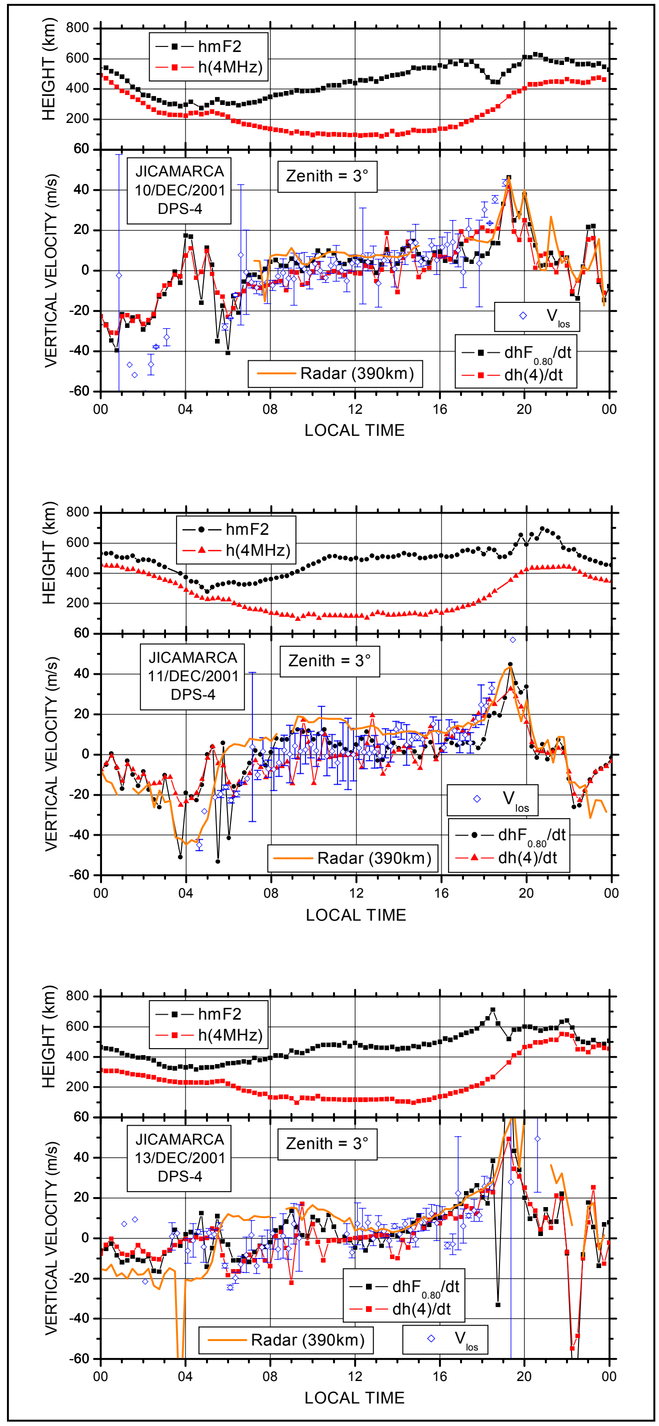

Fig. 2 – Vertical velocities plotted for 10, 11 and 13/Dec/2001: 1) top panels show real height variation along the day for hmF2 (line with black squares) and h(4MHz) (line with red squares); 2)bottom panels show velocity calculated by different techniques together with that measured by ISR at a height of 390km.

ISR makes electromagnetic drift measurements at fixed heights separated in steps of 15km. We got measurements registered at 390km, because there was not critical vertical velocity gradients and had more points to plot.

V_{los} points actually represent an average over measurements taken in a complete sounding, which lasts for a few minutes. Error bars represent the standard deviation. So, we can have an idea about the variability present in those averages. Sometimes it is very large and sometimes, zero. When it is zero, it means that there was only one point to evaluate the average.

Conclusions

Plots of velocities show reasonably good agreement for all techniques around post-sunset – the pre-reversal enhancement peak velocity. It happens because F-layer is at high altitudes – mainly more than 300km during those hours. Production and loss are less important than diffusive effects at those regions and dhF/dt might be considered as very representative of electromagnetic drift (*e.g.* Bittencourt and Abdu, 1981).

Absence of V_{los} points during some hours of the day suggests that the F-layer does not have reflection source points overhead or within 3° of zenith. It means that most of the echoes come from oblique directions. Increasing the value of the zenith angle, obviously, we will get more and more points, however, line-of-sight velocity will have contributions of horizontal component of the movements. This technique as already mentioned above is an effort to take vertical drift values without horizontal component of moving reflection sources. DDAV method of velocity calculation uses sources within 40° of zenith and assumes uniform movement of the layer. So it can have horizontal velocity component contributions in its calculations.

More improvements in the method are necessary to get better data using such technique (line-of-sight-velocity). Although it seems to provide data that show good agreement with velocities calculated with dhF/dt or $dhF_{0.80}/dt$, and even with ISR drift measurements.

Acknowledgments

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