Daytime vertical and zonal velocities from 150-km echoes over Jicamarca

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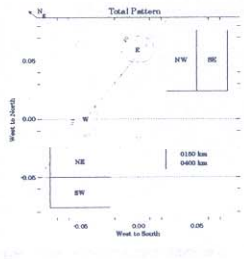
Abstract

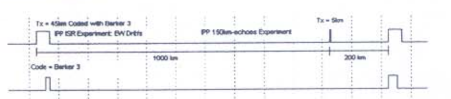
Doppler velocities of 150-km echoes represent the vertical ExB drift velocities at F region altitudes. 150-km observations represent an excellent mean of monitoring the electric fields at equatorial latitudes. Low power observations of 150-km echoes using the JULIA system have been carried out almost continuously since August 2001 at Jicamarca [e.g., *Anderson et al., 2004*]. Most of the observations have been done pointing perpendicular to the magnetic field (B) in the magnetic meridian, allowing the measurement of the vertical component of the ExB drift. However, few campaigns have been carried out with the JULIA system using two oblique beams. With this configuration we are able to measure the zonal velocity component. In order to understand the significance of this new parameter a special experiment has been conducted to obtain concurrently velocities from 150-km echoes and from the east-west drift incoherent scatter radar (ISR) mode perpendicular to B [e.g., *Kudeki et al., 1999*]. From these comparisons (1) we have verified the excellent correlation between their vertical components, and (2) there is a poor to good agreement between their zonal components. The latter result should not be surprising since the F region is strongly coupled to the E region owing to the high conductivity along the magnetic field lines. The E region itself represent high conductivity so the F region and also the region around 150 km responds to the electric filed imposed by the E region. Therefore the observed zonal velocities from 150-km echoes could be an indication of the zonal neutral winds at E region heights few degrees away from the magnetic equator.

Dual Beam Observations

In Figure 1 we show the pointing directions used in our experiment, which are the same as those used for the ISR east-west drift mode *Kudeki et al.* [1999]. The Jicamarca antenna is configured to point simultaneously in two directions, using two independent systems pointing ~2.65° and ~1.90° to the east and west of the geomagnetic meridional plane, respectively. More specific details on the experimental setup are presented by *Kudeki et al.* [1999].



We have conducted two concurrent experiments with the same antenna configuration. Briefly, an ISR experiment was run with the following parameters: Interpulse period of 8 ms (1200 km), 3-baud Barker coded transmitted pulses with a total width of 300 µs, and a baud width of 100 µs to provide a nominal range resolution of 15 km with decoded returns. The 150-km echo experiment, consisted on introducing a shorter uncoded pulse of 33.33 µs (5 km) to the ISR sequence of transmitted pulses delayed by 6.66 ms (1000 km). In both cases, samples were obtained every 5 km from 45 to 1200 km, and complex raw voltages were recorded for each of the four receiving channels. (see figure 2)



Samples between 45 and 1000 km were analyzed with the standard ISR drift procedure [*Kudeki et al.*, 1999] obtaining vertical and zonal drifts every 5 minutes and every 15 km (ISR-15) with very small error bars. Between 1000 and 1200 km ranges, the data were analyzed with 4 coherent integrations and 60 incoherent integrations allowing vertical and zonal velocities every ~1 minute and every 5 km (150km-5). As in the case of the ISR velocities, the 150-km velocities were obtained from the radial velocities measured at the two oblique beams.

In addition, we have done a different processing procedure to the data samples between 100 and 200 km. Since the echoes from these ranges come from EEJ and 150-km irregularities, this portion of the data have been analyzed using 4 coherent integrations and 60 incoherent integrations allowing vertical and zonal velocities estimates every ~1 minute and every 15 km (150km-15).

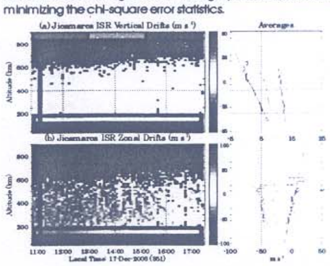
In summary, we have the following vertical and zonal velocity estimates: (a) altitudinal profiles of F region estimates from ISR echoes (ISR-15), (b) from 150-km echoes every 5 km (150km-5), and (c) from 150-km echoes every 15 km (150km-15).

In Table 1 we present a summary of the estimates.

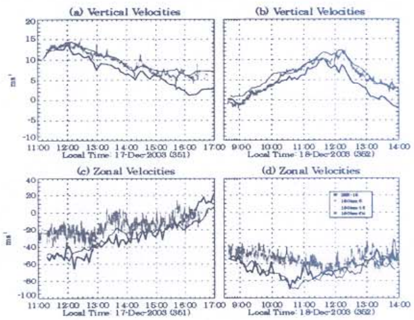
	ISR-15	150km-5	150km-15
Altitudes (km)	200-1000	140-170	140-170
Sampling range (km)	15	5	15
Spectral Fitting	ISR Model	Gaussian	Gaussian
w (m/s)	0.5-2	0.5-1	0.5-1
u (m/s)	8-32	8-16	8-16

Results

In Figure 3 we show the vertical and zonal drift velocities over Jicamarca obtained on December 17, 2003. Values above 200 km have been obtained with the ISR technique. On the right panels, we show averaged values over time periods indicated with the horizontal color bars at the top of Figure 3a, i.e., red, green, and blue values represent averages for 1045-1300, 1300-1515, and 1515-1730 LT, respectively. The velocities around 150 km have been obtained by linearly extrapolating the ISR values. In the case of the contour plot, extrapolated values have been obtained from the 5-minute profiles, while values on the right panels, from the averaged values. The solid straight lines on the right panels represent the fitted values that were obtained by minimizing the chi-square error statistics.



Similar procedure were done with data from December 18,2003. Note that the averaged values of both components show a linear trend as function of altitude and the slope changes as function of time and from day to day. The vertical results are in reasonable agreement with the results reported by *Pingree and Fejer* [1987], namely, almost constant in the early morning and negative gradients in the afternoon. The zonal drifts are almost constant (in altitude) in the morning and with positive gradients in the afternoon. Given the linear behavior as function of altitude, below we also compared the 150-km drift to the extrapolated values obtained every 5 minutes (150km-fit). Time series for both days are shown in Figure 4.

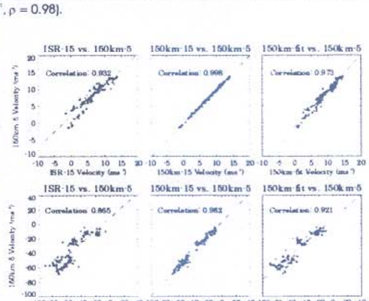


If we compare the 150-km velocities obtained for the specially designed experiment (i.e., 150km-5) with the other three series (all of them averaged every 5 minutes), we find the following results for the vertical velocities:

- There is an excellent agreement with the extrapolated (in altitude) 150-km vertical drifts (150km-fit) with mean (μ_d) and rms (σ_d) differences of 0.58 ms^{-1} and 0.90 ms^{-1}, respectively, and a correlation (ρ) of 0.97.
- There is also an excellent agreement with the reanalyzed ISR raw data around 150 km (150km-15) (μ_d = 0.14ms-1, σ_d = 0.27ms-1, ρ = 0.99)
- Very good agreement with the mean *F*-region vertical drifts (μ_d =-1.68ms^{-1}, σ_d =1.47ms^{-1}, ρ = 0.93).
- Mean *F*-region vertical drifts are smaller (up to 4 ms^{-1}) than the 150-km vertical velocities, particularly in the afternoon hours. This difference is a consequence of the slope of the vertical drifts as function of altitude.

Now if we do a similar comparison with the zonal velocities, we find that:

- Excellent agreement is found with the reanalyzed ISR data around 150 km (150km-15) (μ_d =-2.29ms^{-1}, σ_d = 3.69ms^{-1}, ρ = 0.98).
- The agreement is only poor-to-good with the mean *F*-region (ISR-15) (μ_d =-16.02ms^{-1}, σ_d=10.21ms^{-1}, ρ=0.87) and the extrapolated (150km-fit) (μ_d=15.86 ms^{-1}, σ_d=8.15ms^{-1}, ρ=0.93) values.
- Mean *F*-region zonal drifts are larger (up to 30 ms^{-1}) than 150-km zonal velocities, particularly before noontime hours. Note that despite the discrepancies before noontime, 150-km zonal velocities follow closely the day-to-day variability of the mean *F*-region zonal drifts.



JULIA Observations

Vertical velocities from 150-km echoes are now routinely being observed w power system at Jicamarca (i.e., JULIA). These velocities are allowing a number requiring better time coverage. Lately few campaigns have been carried out with system using two oblique beams (JULIA-EW). With this two-beam configuration we to measure the zonal velocity component. Figure 6 shows a typical results from echoes obtained during these campaigns.

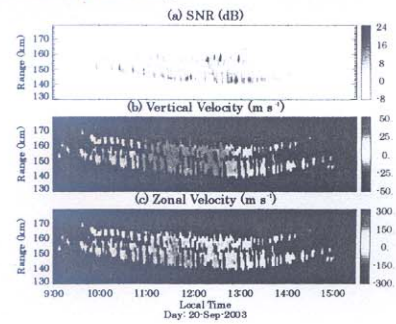
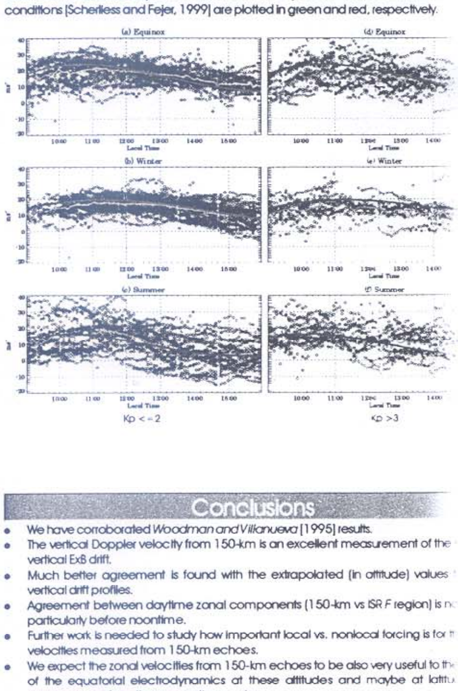


Figure 7 shows vertical drift observations from 5-minute averages obtained JULIA system since August 2001 (more than 300 days). Results are shown for moder conditions (100<F10.7<150) under quiet (kp =<2, left) and disturbed magnetic (kp>3, right) as function of season: equinox (March, April, September, October), wi through August), and summer (November to February. The daily averag observations and the expected drifts from the Equatorial Vertical drift model conditions [Scherliess and Fejer, 1999] are plotted in green and red, respectively.



Kp <=2 Kp >3

Conclusions

- We have corroborated *Woodman and Villanueva* [1995] results.
- The vertical Doppler velocity from 150-km is an excellent measurement of the vertical ExB drift.
- Much better agreement is found with the extrapolated (in altitude) values vertical drift profiles.
- Agreement between daytime zonal components (150-km vs ISR *F* region) is n particularly before noontime.
- Further work is needed to study how important local vs. nonlocal forcing is for t velocities measured from 150-km echoes.
- We expect the zonal velocities from 150-km echoes to be also very useful to th of the equatorial electrodynamics at these altitudes and maybe at latitu degrees away from the magnetic equator.
- Comparisons with other techniques and models should be done to assert the v zonal velocities from 150-km echoes.

References

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