F-region east-west drifts at Jicamarca

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Abstract. F region east-west drifts have been measured at Jicamarca for almost 10 years, using incoherent scatter. The drifts are westward during the day and eastward at night. The daytime drift velocities are about 50 m/s and change very little with season or solar cycle. The evening reversal occurs at about 1600 local time throughout the solar cycle. The maximum nighttime eastward drifts are about 105 and 130 m/s during solar minimum and maximum, respectively. The daytime and nighttime drifts show very little variation with magnetic activity. These Jicamarca incoherent scatter results (especially the reversal times) differ appreciably from results obtained using other techniques, but there appear to be fairly simple explanations for the apparent disagreements.

Introduction

The large number of ionospheric drift measurements made in the last decade have significantly improved our understanding of the worldwide ionospheric electric fields. These measurements, which have been reviewed in a number of papers (e.g., Balsley, 1973; Testud et al., 1975; Blanc and Amayenc, 1976; Blanc, 1979), have formed the basis of recent detailed worldwide dynamo electric field models [Richmond, 1976; Forbes and Lindzen, 1976; Richmond et al., 1980; Blanc and Richmond, 1980].

F region drift measurements have been made at the Jicamarca Radar Observatory (12°S, 76.9°W; magnetic dip 2°N) for over a decade. The vertical drifts have given us a detailed picture of the variation of the equatorial east-west electric fields [Woodman, 1970; Balsley, 1973; Fejer et al., 1979a, b; Gonzales et al., 1979]. The F region east-west drifts have been observed less extensively at Jicamarca; the only previous study was published by Woodman [1972]. The F region east-west drifts have also been measured at Thumba (magnetic dip 0.5°S), using spaced receiver techniques [Chandra et al., 1970; Rastogi et al., 1972], but drifts measured in this way differ substantially from those observed at Jicamarca [Balsley, 1973]; a point we shall return to later. The purpose of this paper is to describe all the east-west drift measurements made at Jicamarca since 1970 and to compare these observations with other related data (such as the Indian results) and with available theory.

Measurement Techniques

The procedure used for measuring the F region drifts at Jicamarca was described in detail by Woodman and Hagfors [1969] and Woodman [1972]. The large Jicamarca antenna is split into two beams, which are both perpendicular to the magnetic field and point 2.45° to the east and 4.33° to the west of vertical, giving a net split of 6.78°. The line of sight drifts from these two directions are then combined to give the F region east-west and vertical drifts. Usually the drifts are measured from 275 to 500 km with a resolution of 25 km. The integration time is typically about 5 min, and the accuracy of the drifts from these observations is about 1-2 m/s for the vertical drifts and about 12 m/s for the east-west drifts.

Results

We have examined all the east-west drift data obtained at Jicamarca from 1970 through May 1977. The drifts from 1970 to 1971 and from 1974 to 1977 were taken to be representative of the results during solar maximum and solar minimum, respectively. The measurements from 1972 to 1973 were very sparse and will not be included in our study.

Fejer et al. [1979a] have shown that the equatorial F region vertical drifts during solar maximum and solar minimum differ substantially. In contrast, the F region east-west drifts change very little with solar cycle, as is shown in Figure 1 (positive drifts are eastward). The triangles in this case indicate the periods when the number of samples used was smaller than or equal to 3. The number of samples per plotted point varies from 45 and 26 at about 2000-2100 local time during solar minimum and maximum, respectively, to only a few in the early morning period. The late night and early morning data were also less accurate because of the small
drifts show no such reversals, a result which has also been pointed out by Woodman [1972].

Discussion

The equatorial ionospheric drifts are controlled by the neutral wind generated E region dynamo [e.g., Maeda and Kato, 1966; Matsushita, 1969, 1977; Forbes and Lindzen, 1976] and by F region polarization fields [Kishbath, 1971; Heelis et al., 1974; Matuura, 1974]. The E and F region dynamo theories were recently reviewed by Richmond [1979]. During the equatorial daytime the F region plasma drifts are strongly coupled to the E region at somewhat higher latitudes by the highly conducting magnetic field lines. The daytime equatorial F region east-west drifts are then representative of the E region east-west neutral winds which generate the vertical electric fields in the F region [e.g., Woodman, 1972]. The results presented here suggest that these E region neutral winds are essentially unchanged throughout the solar cycle.

At night the coupling between the E and F regions decreases because of the large decrease in the E region electron density. F region polarization electric fields are set up which the E region cannot short out. As a result the nighttime east-west drifts become nearly equal to the F region neutral winds which generate these fields [Rishbeth, 1971; Woodman, 1972; Heelis et al., 1974]. Our results show that, as was reported previously by Woodman [1972], the nighttime eastward drifts have a maximum amplitude of the order of 120 m/s occurring at about 2100 local time. These drifts at Jicamarca change little with season and solar cycle, and their direction and amplitude are in excellent agreement with the recent neutral wind measurements from airglow observations at Kwajalein (magnetic dip 8.4øN) reported by Sipler and Biondi [1978], which were also observed to decrease late at night. Bittencourt et al. [1976] obtained somewhat larger neutral winds, maximizing at about signal to noise ratios obtained during these periods. The drifts were westward during daytime with a maximum average value of about 45 m/s between 1000-1300 local time. The nighttime eastward drifts are considerably larger during both solar maximum and solar minimum. The maximum drifts are about 130 m/s, respectively, and occur at about 2100 LT. For the rest of the night the drifts do not change with solar cycle except perhaps in the early morning period. As we just pointed out, however, the early morning results are somewhat uncertain.

The seasonal averages of the data for solar maximum and minimum conditions are shown in Figure 2. The solar minimum averages are slightly different from those presented by Richmond et al. [1980] because of the slightly different definitions used for the seasonal periods. There is no pronounced seasonal variation evident in our data, although there is some indication that daytime drifts are largest in the summer and that nighttime drifts are largest in the summer during solar maximum, but there were only a few data points during most of the solar maximum summer period, and therefore these latter results might not be reliable.

Figure 3 illustrates the day to day variation and wavelike fluctuations of the drifts. The large variability of the nighttime drifts is due in part to the smaller signal to noise ratio. This is especially true during solar minimum. The general characteristics of the daily variation are, however, very clear.

The F region vertical drifts change appreciably with magnetic activity [e.g., Fejer et al., 1979b; Gonzales et al., 1979], but no such effect was seen in these east-west drift data (see Figure 4). The late night and early morning periods were omitted from this figure because of the small number of samples available. During magnetically disturbed periods the equatorial vertical drifts frequently reverse their direction for periods from a few minutes to a few hours [Fejer et al., 1979b], but the east-west
The equatorial vertical drifts are frequently strongly disturbed during periods of high magnetic activity [e.g., Fejer et al., 1976; Rastogi et al., 1979b; Gonzales et al., 1979]. In contrast, the results shown here indicate that the east-west drifts do not depend on magnetic activity; any electric fields of magnetospheric origin have only a zonal component and directly affect only the vertical drift. However, it is also possible for heating associated with magnetic disturbances to change the equatorial drifts by altering the global thermospheric circulation. These effects would be felt at the equator several hours after the main disturbance observed at high latitudes [Blanc and Richmond, 1980]. This disturbance dynamo effect on the east-west drifts will be considered in a separate paper. Equatorial scintillations of VHF satellite transmissions are known to be caused by the electrojet irregularities [Basu et al., 1977].

The evening reversal of the Jicamarca drifts from westward to eastward occurs at about 1600 local time, but rocket observations using barium clouds [Rieger, 1974] have indicated the occurrence of large east-west drifts at 1900 local time, and spaced receiver measurements have shown a reversal at about 2000 local time. This disagreement can be explained as being a result of the evening circulation pattern recently suggested by Valenzuela et al. [1980]. Electric field measurements from a series of rocket measurements in the equatorial region indicate an evening circulation with westward winds in the lower F region and eastward winds near the F region peak and above. In addition, Heelis et al. [1974] have shown that model calculations, including E and F region dynamo fields, result in westward drifts up to about midnight below 220 km, while eastward drifts are present at higher altitudes hours earlier.

The altitudinal variation of the east-west drifts is the result of the combined effect of the E and F region dynamo fields. The efficiency of the F region dynamo is determined by the height of the F layer and by the ratio between the E and F region electron densities, a ratio which changes drastically with altitude in the evening and early night hours. At night the drifts in the equatorial F layer are determined primarily by the F region dynamo; the F region winds rapidly produce a polarization electric field which causes the plasma to drift eastward at very nearly the wind velocity. In the 'valley' just below the F layer, however, the densities are very low, and the plasma drifts will be controlled primarily by E region dynamo fields generated by E region winds north and south of the equator and coupled to the valley region by the curving magnetic field lines. Our data presented here correspond to the F layer itself. Additional numerical studies are needed.
to understand better the details of the F region
dynamo fields. In these calculations the
electron density changes resulting from the
drifts must be included self consistently (A. D.
Richmond, private communication, 1980).

Acknowledgments. We thank the staff of the
Jicamarca Observatory for their help with the
observations. This work was supported by the
Aeronomy Program, Division of Atmospheric
Sciences, of the National Science Foundation
through grant ATM-78-12323. The Jicamarca
Observatory is operated by the Geophysical
Institute of Peru, Ministry of Education, with
support from the National Science Foundation and
the National Aeronautics and Space Administra-
tion.

The Editor thanks S. Basu and A. D. Richmond
for their assistance in evaluating this paper.

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