Comparison of f_0F_2 Characteristics at Nearby Equatorial Locations in the South America Region

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The daily variation characteristics of ionospheric f_0F_2 at two locations on the magnetic equator in the American region viz. Huancayo (12°S , 75°W , Dip angle 2°N) and Natal (5°S , 35°W , Dip angle $1^\circ\text{--}2^\circ\text{S}$ in 1958–62) show considerable differences. Possible causes could be differences in electrodynamic effects and/or particle precipitation from magnetospheric regions at Natal, which is near the South Atlantic Geomagnetic Anomaly.

1. Introduction

The daily variation patterns of ionospheric f_0F_2 in the equatorial, low and middle latitudes have been studied in detail by various workers. From sunrise onwards, f_0F_2 increases rapidly up to about noon, after which it drops slowly, reaching a minimum level near dawn. However, the near-noon maximum value is not highest near equator (where the sun shines brightest) but shows a smooth variation with magnetic dip, with a minimum near magnetic equator and crests near magnetic dips 30°N and S . LYON and THOMAS (1963), RAO and MALHOTRA (1964) and THOMAS (1968) have described the main features of this equatorial anomaly in different longitudinal zones viz. American, African and Asian sectors from data obtained during IGY, i.e., at the solar maximum, and have reported considerable longitudinal differences.

The equatorial anomaly is explained as a sort of 'fountain effect' where, due to $\vec{E} \times \vec{B}$ effects, ionization at the dip equator is lifted upwards and diffuses down along the magnetic field lines to pile up at the crests on either side (MARTYN, 1955; DUNCAN, 1960). From a theoretical study, ANDERSON (1973) has attempted to explain the differences of f_0F_2 characteristics in the Asian and American sectors as due to differences in the diurnal evolution of the $\vec{E} \times \vec{B}$ vertical drifts.

The South American region has some magnetic peculiarities. Firstly, the lowest geomagnetic field is near the eastern Brazilian coast. Secondly, the magnetic dip equator, which is parallel to the geographic equator but 13° south of it in the Peruvian region (about 75°W), curls northwards on the eastern side. Thirdly, this curl has a secular variation, so that, in the Brazilian east coast, the dip equator is presently shifting in geographic latitude, by about $1/4$ degree per year, northwards (see the Magnetic Inclination map for epoch 1975.0, compiled by U.S. Geological survey in collaboration with the U.S. Naval Oceanographic Of-

fice and with the assistance of NOAA). It would be of interest, therefore, to compare the f_0F_2 characteristics at equatorial locations in this region. Continuous and good quality data from conventional ionosondes are available for Huancayo, Peru (12°S , 75°W), which is almost on the dip equator (Dip 2°N) for the last few decades. During IGY and later years, data are also available for Natal (5°S , 35°W) which presently (1983) has a Dip angle of 13°S but during IGY, had a Dip angle of only about 1°S . The continuity or quality of Natal data is not as good as that of Huancayo. Here, we present the results of a study of monthly median 24 hourly values of f_0F_2 for months for which data were available at both the locations during 1958–62.

Fig. 1. Average monthly median f_0F_2 at Huancayo (full lines) and Natal (crosses) for E months (Equinoxes; March, April, September, October) during 1958–62. Months for which data were available are indicated.

2. Results

Figure 1 is a plot of average f_oF_2 for the E months (Equinoxes; March, April, September, October) for 1958 (at the top), 1959, 1960, 1961, 1962 and finally the average 1958–62 for Huancayo (full lines) and Natal (crosses). The months for which data were available for both locations are indicated. The following may be noted:

(1) There is a solar cycle variation of f_oF_2 . For Huancayo, the peak value at about 1000 Hr was about 15 MHz in 1958 which reduced to about 9 MHz in 1962. The same was also true for Natal.

(2) For later hours, there is a considerable difference between the behaviour

Fig. 2. Average monthly median f_oF_2 at Huancayo (full lines) and Natal (crosses) for J months (May, June, July, August) during 1958–62. Months for which data were available are indicated.

of f_oF_2 at the two locations. At Huancayo f_oF_2 values drop by almost 2–3 MHz from 1000 Hr to 1300 Hr. But at Natal, f_oF_2 drops very little, and later increases to reach a maximum value at about 1600 Hr, when Natal f_oF_2 exceeds Huancayo f_oF_2 by as much as 2 MHz (about 20%).

(3) The night values at the two locations are almost similar. It must be remembered, however, that night values at Natal are not very reliable.

Figure 2 shows similar plots for J months (May, June, July, August). These are months of southern winter and hence both Huancayo (12°S) and Natal (5°S) are farthest away from the subsolar point ($\sim 23^\circ\text{N}$). The large excess of ionization at Natal as compared to Huancayo in the afternoon hours is again seen. However, the night values seem to be lower at Natal.

Fig. 3. Average monthly median f_oF_2 at Huancayo (full lines) and Natal (crosses) for D months (January, February, November, December) during 1958–62. Months for which data were available are indicated.

Fig. 4. Monthly median f_oF_2 at Huancayo (full lines) and Natal (crosses) for the year 1962.

Table 1. f_oF_2 at Natal VIS-A-VIS f_oF_2 at Huancayo in 1962.

	Larger	Smaller
Daytime	March	January
	April	February
	May	
	June	November
	July	December
	August	
	September	
	October	
Nighttime	January	April
	February	May
	March	June
	October	July
	November	August
	December	September

Figure 3 refers to D months (January, February, November, December). Since the subsolar point has an extreme of 23°S in these months, both Huancayo (12°S) and Natal (5°S) would be to the north of the subsolar point. Natal f_0F_2 values seem to be consistently smaller than Huancayo f_0F_2 values during the daytime, and higher at nighttime. For 1962, data were available for both the locations for all the twelve months. Figure 4 shows the plots. The daytime and nighttime values of f_0F_2 at Natal (crosses) relative to Huancayo (full lines) in various months of 1962 are as given in Table 1.

Thus, for daytime values, the transition occurs between February–March and October–November. For nighttime, the transition is between March–April

Fig. 5. Average annual median f_0F_2 at Huancayo (full lines) and Natal (crosses).

and September–October. Due to lack of data, it is difficult to say whether this pattern for 1962 is representative for all other years, too.

Huancayo and Natal have geographical latitudes 12°S and 5°S respectively. The sun is overhead at Huancayo in early November and then again in early February, while at Natal, it is overhead in early October and early March. It is doubtful, however, that this small geographical latitude difference would cause such a large difference ($\pm 20\%$) in f_oF_2 magnitudes, through differences in solar zenith angle. Figure 5 shows a plot of annual average f_oF_2 in different years as also for all years combined. The excess at Natal in the afternoon hours is clearly visible. Table 2 summarizes the results of Figs. 1, 2, 3, and 5.

3. Discussions

Huancayo (Dip 2°N) and Natal (Dip $1^\circ\text{--}2^\circ\text{S}$ in 1958–62) were both almost on the dip equator. Their geographical locations (12°S and 5°S) are also almost similar. The large differences in f_oF_2 characteristics at the two locations could probably be due to large differences in electrodynamic effects, and/or perhaps some precipitation of particles from the magnetospheric regions (PAULIKAS, 1975; GLEDHILL, 1976). This needs further investigation by using data from a closer network of observatories.

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Table 2. Comparison of f_oF_2 values at Huancayo and Natal.

Year	Daytime maximum f_oF_2 (MHz) at about 1600 hr								Nighttime minimum f_oF_2 (MHz) at about 0500 hr							
	Huancayo				Natal				Huancayo				Natal			
	E	J	D	Annual	E	J	D	Annual	E	J	D	Annual	E	J	D	Annual
1958	11.8	9.8	13.0	11.0	14.2	12.0	13.0	13.0	5.6	5.0	6.2	5.4	7.2	4.0	7.6	6.2
1959	11.6	10.0	12.6	11.4	14.6	12.0	11.8	12.6	5.4	5.0	5.0	5.0	6.4	4.2	7.4	6.0
1960	11.8	9.0	12.6	11.4	13.0	11.8	12.0	12.2	4.8	4.2	5.8	5.0	5.8	3.2	5.8	5.4
1961	10.4	8.4	10.8	9.8	12.0	10.0	10.0	10.6	3.4	3.6	3.8	3.2	3.4	2.6	4.2	3.4
1962	9.6	7.6	9.8	9.0	11.0	9.4	9.0	9.6	3.4	2.8	2.2	2.8	3.4	2.0	3.0	2.8
1958–62	10.8	9.0	11.6	10.6	12.4	10.8	10.8	11.4	4.0	4.0	4.2	4.2	4.8	3.2	5.6	4.6

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