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Some Anomalous Features of the Ionospheric F2-Layer at Low Latitude Conjugate Places

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The diurnal variation of the F2-layer critical frequency (f0F2) is compared with the diurnal variations of the horizontal component H of the earth's magnetic field and of the declination D at a pair of low latitude conjugate stations in the Pacific and the Atlantic zones for a medium-low solar activity period. It is shown that the day-time bite-out in f0F2 and its seasonal anomaly are dependent on the characteristic daily variation of the H-field. There is also an indication of the effect of E-W declination on the diurnal variation of f0F2 at places near magnetic dip 45-50° as explained by H. Kohl, J. W. King & D. Eccles [*J. atmos. terr. Phys.*, **31** (1969), 1011]; such effect is not observed at low latitudes.

The day-time depression in f0F2 seems to be more pronounced at Port Stanley in summer than at its northern conjugate Puerto Rico, perhaps because of the additional effect of the neutral wind-associated vertical drift of ionization, for which the situation of Port Stanley (mean magnetic dip = 46.3°) is very favourable.

1. Introduction

It is now an established fact that the F2-layer ionization is under profound geomagnetic control and that there are longitudinal anomalies in its distribution. In the wake of the observational analyses and theoretical studies made by some workers[1-9] much interest is evinced in the consideration of the effects of neutral wind and magnetic declination to explain the normal and disturbed-day variations of the F2-layer, at mid-latitudes particularly. However, a concise picture relating the variations of f0F2, H and D is lacking.

The purpose of this paper is to examine the manner in which the zonal north-south asymmetry in the diurnal variation of f0F2 is related, if at all, to the variations of the H-field and D in the 60°W and 165°W sectors. The particulars of the pairs of conjugate places are listed in Table 1.

The monthly mean diurnal variations of f0F2, H and D are expressed in terms of departures of their hourly mean values from the 24-hr mean value. This gives an idea of the range of daily variation and also the duration for which the hourly values are higher and lower than the mean reference level. The mean reference values of f0F2, H and D are shown at the sides in the

TABLE 1—DETAILS OF CONJUGATE PLACES CHOSEN FOR THE STUDY OF ZONAL ASYMMETRY IN DIURNAL VARIATION OF f0F2

Station	Geographical coordinates		Mean magnetic dip	Mean declination	Mean H-field (γ)
(*a*) Puerto Rico	18.5°N	67.2°W	52.5°N		
(*b*) San Juan	18.1°N	66.2°W	51.1°N	7°36′W	27654
(*a*) Port Stanley	51.7°S	57.9°W	46.3°S		
(*b*) Trelew	43.3°S	65.3°W	39.0°S	8°51′E	22604
(*a*) Hawaii (Maui)	20 8°N	159.8°W	38.5°N		
(*b*) Honolulu	21.3°N	158.0°W	42.6°N	11°35′E	28061
(*a*) Rarotonga	21.2°S	159.8°W	39.0°S		
(*b*) Apia	13.8°S	171.8°W	30.0°S	11°58′E	34793

figures for northern (N) and southern (S) stations.

2. Diurnal Variations of *f*0F2, *H* and *D* in the 60°W Sector near 50° Dip Angle

Fig. 1 shows the mean diurnal variations of *f*0F2, *H* and *D* for winter (December for northern station and June for southern station) and summer of 1961 at the magnetically near-conjugate ionospheric stations Puerto Rico and Port Stanley and corresponding magnetic observatories at San Juan and Trelew. The mean Zurich sunspot number in June was 77 and in December it was 40, the annual mean being 54.

The most striking feature of the diurnal variation of *f*0F2 at these conjugate places near the Sq-current focus is a day-time bite-out effect in winter at Puerto Rico while in summer at Port Stanley, the latter being more marked than the former. However, at Puerto Rico in summer, *f*0F2 continued to be below the mean reference level until about 1100 hrs and its day-time maximum was delayed to 1700 hrs. This seasonal anomalous characteristic of the F2-layer is probably a manifestation of the typical variations of the *H*-field and *D* at these places in the respective seasons. The amount of bite-out or the deviation of diurnal variation of *f*0F2 from its normal solar-controlled variation seems to be governed by the magnitude and rate of daily variation of the *H*-field in a particular interval. The curves in Fig. 1 also show that the afternoon maximum of *f*0F2 corresponds with that of magnetic declination, but this correspondence is discernible when the effect of the vertical drift of F2-ionization is not appreciable. The explanation given by Kohl *et al.*[1] for the effect of *D* on the diurnal variation of *f*0F2 seems to fit in here. Furthermore, there is a close similarity between the diurnal variations of magnetic declination in the north and the south with about 2-hr phase delay in the south. Such similarity is not seen in the variations of the *H*-field which fact explains the seasonal anomaly in the bite-out of *f*0F2 in the north and the south.

3. Diurnal Variations of *f*0F2, *H* and *D* in 165°W Sector near 40° Dip Angle

North-south asymmetry in the variation of *f*0F2 exists even at low latitudes, such as at Hawaii and Rarotonga in the Pacific. To see if this asymmetry is also a manifestation of the differences in the variations of the geomagnetic elements, diurnal variations of *f*0F2, *H* and *D* are compared in Fig. 2 for winter and summer months of the year 1963 (data available with the authors). The sunspot number in June 1963 was

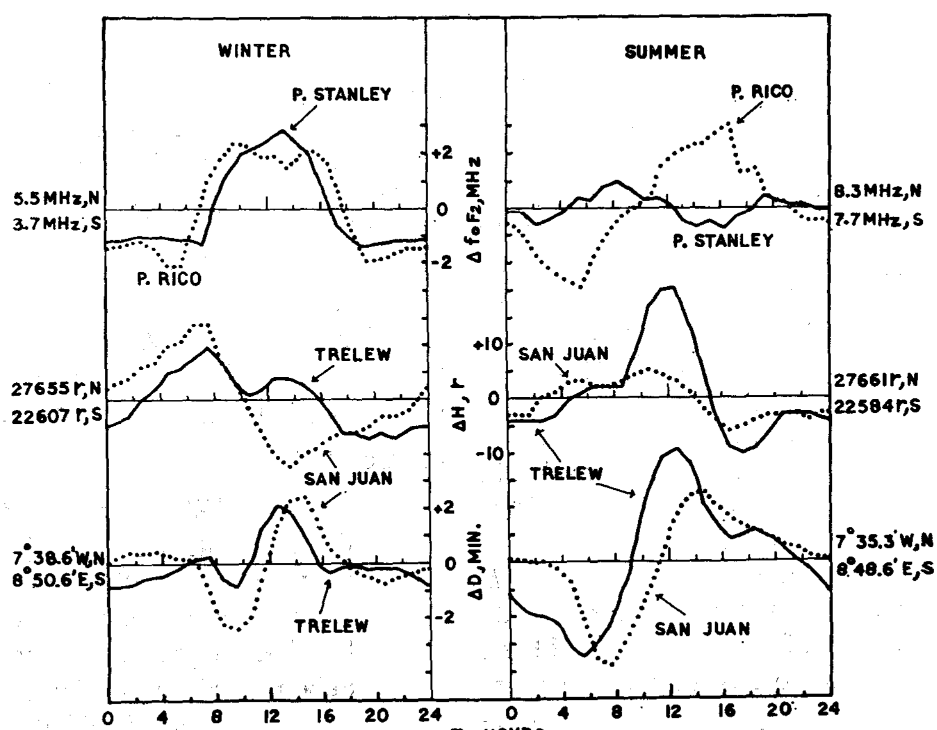

Fig. 1—Monthly mean diurnal variation of *f*0F2, *H* and *D* at conjugate places in the 60°W sector in the magnetic dip zone 45-50° during winter and summer. [Daily mean values are given at the sides for northern (N) and southern (S) stations]

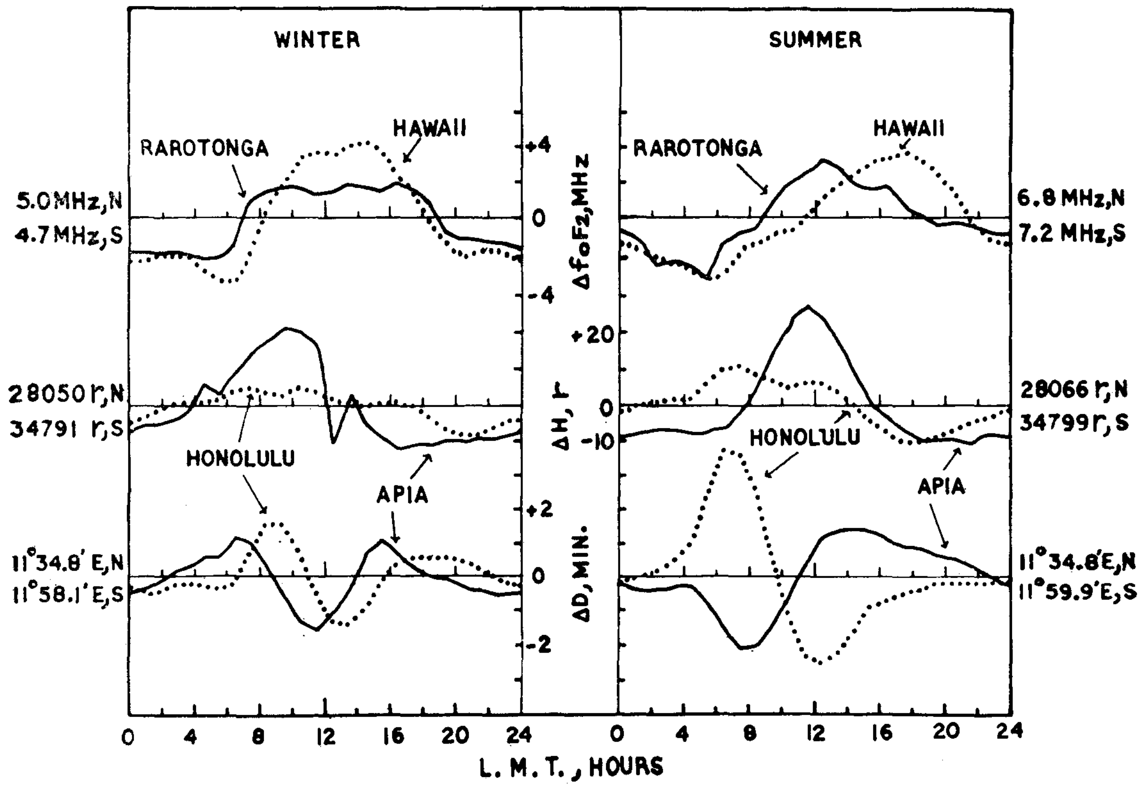

Fig. 2—Monthly mean diurnal variation of f0F2, H and D at conjugate places in the 165°W sector near the magnetic dip 40° during winter and summer [Daily mean values are given at the sides for N and S stations]

36 and in December it was 15, the annual mean being 28. It is seen that the diurnal variation of f0F2 at Rarotonga does not show a clear day-time maximum in winter as it happens at Port Stanley. Also the low day-time values of f0F2 at Rarotonga correspond with large daily variation of the H-field at a nearby magnetic observatory in Apia as compared to that at its northern counterpart. In summer, however, the diurnal variation of f0F2 at Rarotonga shows a clear midday maximum and it seems to be in phase with that of the H-field. Apia, being at a lower latitude than Honolulu, has a larger range of diurnal variation of the H-field. There is no magnetic observatory close to Rarotonga. One may notice the contrast that whereas the situation regarding the diurnal behaviour of the F2-layer at Hawaii is more or less similar to that at Puerto Rico in the north, that at Rarotonga it is different from what it is at Port Stanley in the south. Seasonal differences in the H-field and D are also to be noticed at the pairs of conjugate places in the two longitude zones considered here. An important point to note is that the declination at the low-latitude pair of stations in the Pacific varied almost in antiphase during summer. Such an antiphase diurnal variation appears to have resulted from the suppression of the morning maximum observed in winter at Apia and evening maximum observed at Honolulu with some seasonal phase shift in opposite directions. It may be pointed out here that both Hawaii and Rarotonga have east declination while for the other pair, Puerto Rico has west declination and Port Stanley has east declination, but this does not explain why the former two stations have antiphase variation of declination in summer while the latter have similar variation of declination in winter as well as summer. Further, at low latitudes there is no indication of a correspondence between the maxima of the diurnal variation of f0F2 and D. The time of pre-sunrise minimum of f0F2 at a place depends essentially on the length of night in different seasons.

4. Conclusions

(1) In the 60°W sector near 45-50° dip, the day-time bite-out in f0F2 is observed in winter at Puerto Rico, whereas it is so in summer at its southern conjugate, Port Stanley. This seasonal anomaly is probably related to the large range of daily variation of the H-field at a place in the respective season. Further, Port Stanley is at a higher geographic latitude than Puerto Rico and its magnetic dip is close

to 45° at which maximum effect of neutral wind-associated vertical drift of F2-ionization is expected in addition to that caused by electromagnetic forces. The large daytime depression of *f*OF2 in summer at Port Stanley is probably due to this reason.

(2) The time of afternoon maximum of *f*OF2 seems to follow the direction of the declination at places near 45-50° dip as expected in the northern and southern hemispheres. Such correspondence is not found at low latitudes.

(3) The north-south asymmetry in the diurnal variation of *f*OF2 in winter and summer at Hawaii and Rarotonga can be linked up with the seasonal differences in the variation of the *H*-field and the declination. A striking feature of contrast is the large antiphase diurnal variation of declination in summer at Honolulu and Apia. Such a seasonal shift in phase of the variation of *D* from winter to summer is not found at 45-50° dip in the 60°W sector.

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