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Diurnal Behaviour of Midlatitude F-region Parameters in Summer

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Using total electron content (N_T) measurements at Auckland (AKL) (37·5°S; 175·0 °E) and Invercargill (INV) (46·5°S; 168·4°E) and peak electron density (N_m F_2) data at AKL and Christchurch (CHR) (43·5°S; 172·8°E) for summer months from 1965-66 to 1973-74, a study is made of the day-to-day changes in the diurnal behaviour of midlatitude F-region, with particular emphasis on the bite-out pattern (i.e. one with forenoon and late evening maxima with a depression around midday). On an average, the nature of the asymmetry of the bite-out shows a more or less systematic behaviour with the phase of the solar cycle. The evening maximum is larger than the morning maximum during low solar activity conditions and the opposite is the behaviour during high solar activity conditions. Considering only those days on which bite-out is observed simultaneously, it is noticed that there is statistically a significant correlation of the day-to-day changes in the structure of the bite-out in N_T at AKL and INV, in N_m F_2 at AKL and Christchurch (CHR) and in N_T and N_m F_2 at AKL and CHR. The results suggest a role of global atmospheric neutral air winds in the day-to-day variability of the bite-out pattern in N_T and N_m F_2 at middle latitudes.

1. Introduction

Ionospheric F-region exhibits considerable day-to-day variability both in the magnitude and the diurnal behaviour of its two widely used parameters, peak electron density (N_m F_2) and total electron content (N_T).[1-8] Rao *et al.*[4] interpreted the day-to-day changes in F-region at temperate latitudes as due to changes in local atmospheric conditions in the thermosphere. Kane[8] suggested the day-to-day variability at middle latitudes due to erratic equatorward neutral winds that originate in polar regions intermittently, even under quiet conditions, creating convective cells that result in ionospheric irregularities of scale length of about 3000 km and wander slowly about the globe. The recent study of the author suggested a role of meridional neutral air winds, associated with perturbations of energy input into the auroral regions, in the day-to-day variability of midlatitude F-region electron density during winter daytime conditions.[9]

In this paper, we deal with some aspects of the day-to-day changes in the diurnal behaviour of ($N_m F_2$) and (N_T) at midlatitudes during summer months. The study is based on the systematic and extensive series of N_T measurements at the two midlatitude stations, Auckland (37·5°S; 175·0°E) and Invercargill (46·5°S; 168·4°E) using vhf transmissions from the geostationary satellites SYNCOM-3 and ATS-1. The $N_m F_2$ data from the nearby ionosonde stations, viz. Auckland and Christchurch (43·5°S, 172·8°E), have been used to supplement the N_T measurements and to provide information about the entire F-region. The basic data used were the hourly values of $N_m F_2$ and N_T at the stations mentioned for the local summer months (Nov., Dec., Jan. and Feb.) of each year from 1965-66 to 1973-74, covering the last solar cycle.

2. Observations and Analysis

A careful scrutiny of the computer drawn diurnal plots of N_T and N_m F_2 shows that the diurnal variation of these parameters exhibits three basic patterns which may be described as follows : (i) those with two maxima, one in the forenoon and the other in the late evening period, with a minimum around midday, (ii) those with only one maximum in the forenoon period, and (iii) those with only one maximum in the late evening period. Pattern (i) resembles the mean diurnal variation of N_m F_2 during summer months at midlatitudes[10] and will be referred to as the bite-out pattern. Pattern (iii) resembles the extensively discussed aspect of midlatitude F-region, namely, the summer evening-increase of F-region peak electron density.[11-15] In this study, we are mainly concerned with the bite-out pattern. For each day, the maxima and minima in the diurnal variation of N_T and N_m F_2 at the four stations under consideration are picked up by a computer programme that uses second difference interpolation. In doing so, only maxima with an amplitude greater than or equal to 3×10^{15} electron/m^2 in N_T and $1{\cdot}5 \times 10^{10}$ electron/m^3 in N_m F_2 are taken into consideration. No distinction is made here between magnetically quiet and disturbed days and all the data are used. For those days on which

FIG.1

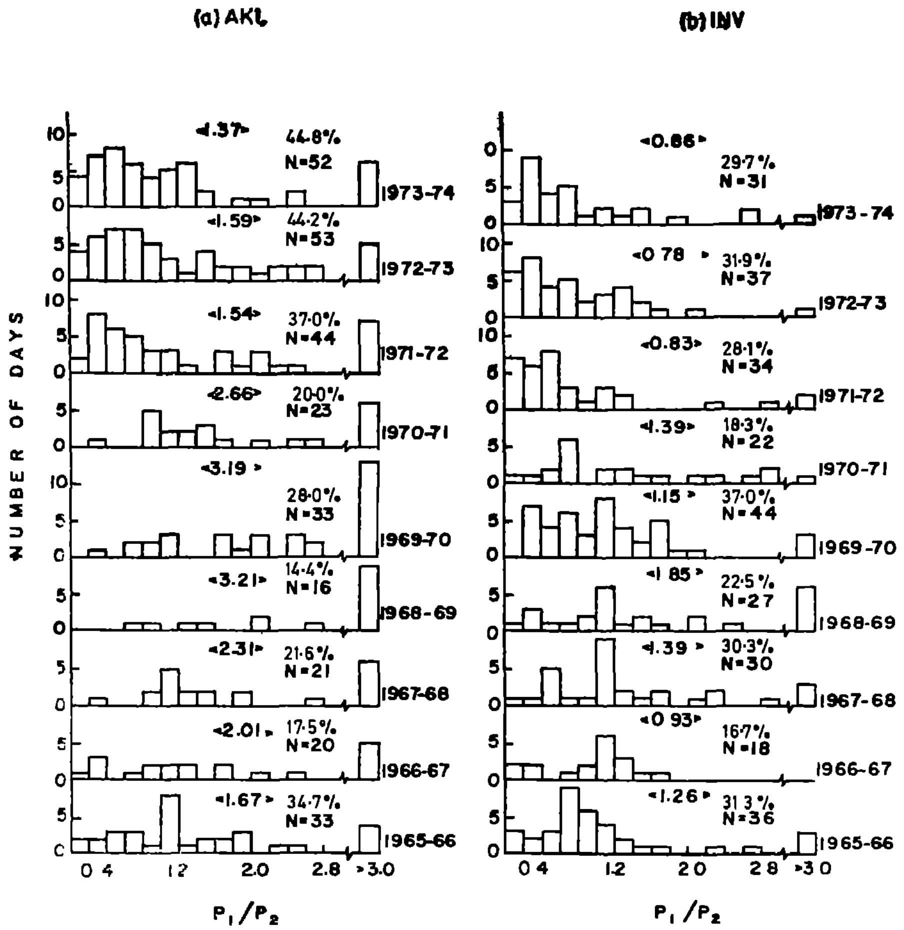

FIG.2

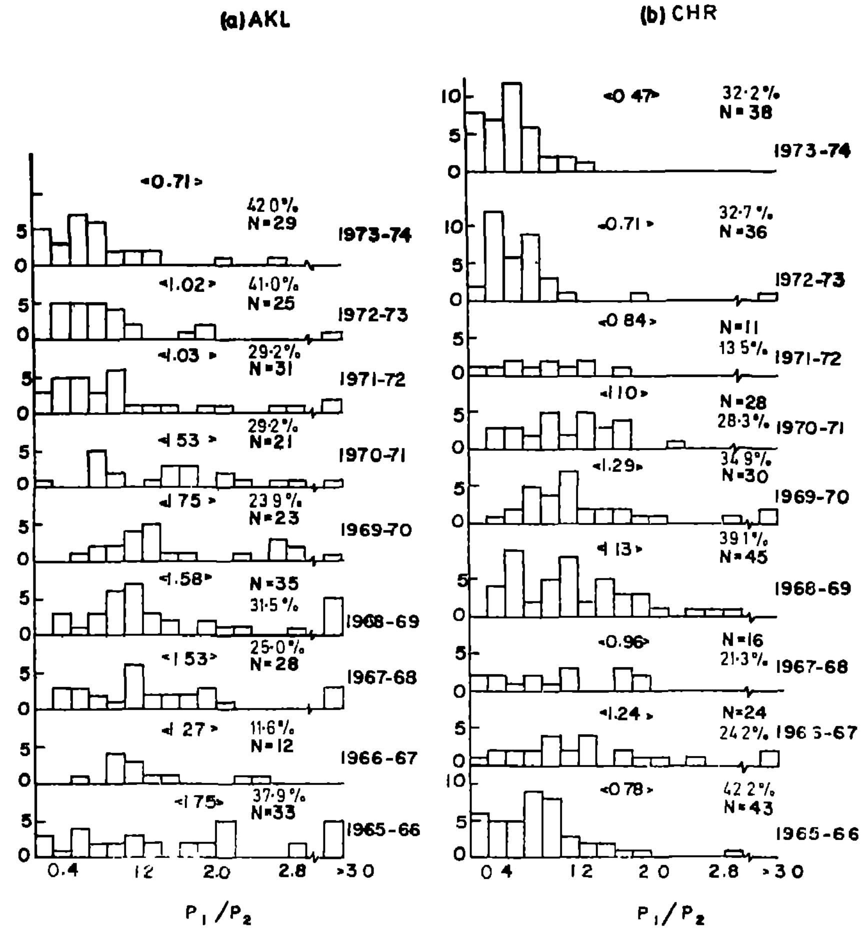

Fig. 1 – Distributions of the ratio P_1/P_2 as observed in the diurnal variation of N_T at Auckland (AKL) and Invercargill(INV) for each summer from 1965-66 to 1973-74. [Also shown in the diagram are the values of P_1/P_2 (within V brakets), the actual number of days (N) and the percentage of the total number of days on which the bite-out pattern is observed during each summer.]

Fig. 2—Same as in Fig. 1 but depicting the behaviour observed in the diurnal variation of N_m F_2 at Auckland and Christchurch (CHR)

the diurnal pattern exhibited a clear cut bite-out, the ratio of the amplitude (with respect to the midday minimum) of the forenoon maximum to the late evening maximum P_1/P_2 is evaluated. This ratio provides a quantitative measure of the relative amplitudes of the two maxima, i.e. asymmetry in the bite-out pattern. A detailed morphological study of the bite-out pattern has been attempted from the values of P_1/P_2.

3. Results

Fig. 1 shows the distributions of the ratio P_1/P_2 observed in the diurnal variation of N_T at Auckland (AKL) and Invercargill (INV) for each summer from 1965-66 to 1973-74. A similar representation is made in Fig. 2 of the behaviour noticed in N_m F_2 at AKL and Christchurch (CHR). It may be seen that at AKL the occurrence of the bite-out, both in N_T and N_m F_2, shows a more or less systematic inverse trend with solar activity. This behaviour is not so apparent in N_T at INV and in N_m F_2 at CHR. Cross-correlation studies (using an appropriate index system for the bite-out occurrence) showed no systematic and significant dependence of the occurrence of the bite-out on solar and geomagnetic activity. The structure of the bite-out both in N_T and N_m F_2 exhibits considerable day-to-day variability and this behaviour is noticed irrespective of the phase of the solar cycle. Cross-correlation studies showed that the day-to-day changes in P_1/P_2 are not dependent on changes in solar, geomagnetic and auroral activities. The structure of the bite-out, on the average, shows the tendency for a more or less systematic variation with the phase of the solar cycle. During periods of low solar activity, the amplitude of the late evening maximum is more than the morning maximum (i.e., $P_1/P_2 < 1$) and the opposite is the behaviour ($P_2/P_1 > 1$) during periods of high solar activity. This can be clearly seen from the average values of P_1/P_2 presented in Figs. 1 and 2.

Fig. 3(a) shows mass plots of the simultaneous values of P_1/P_2 observed in the diurnal variation of N_T at AKL and INV (separation: 1000 km) and of N_m F_2 at AKL and CHR (separation: 700 km), during summer months over the entire nine-year period from 1965-66 to 1973-74. It is quite evident that there is a significant correlation ($P > 0{\cdot}01$) of the day-to-day changes in the structure of the bite-out at the station-pairs considered. This suggests that, in gross behaviour, the day-to-day changes in the diurnal variation of N_T and N_m F_2 correlate well over a distance of at least 1000 km in the north-south direction. The following features are also evident from Fig. 3(a). First, the values of P_1/P_2 in N_T are, in general, higher

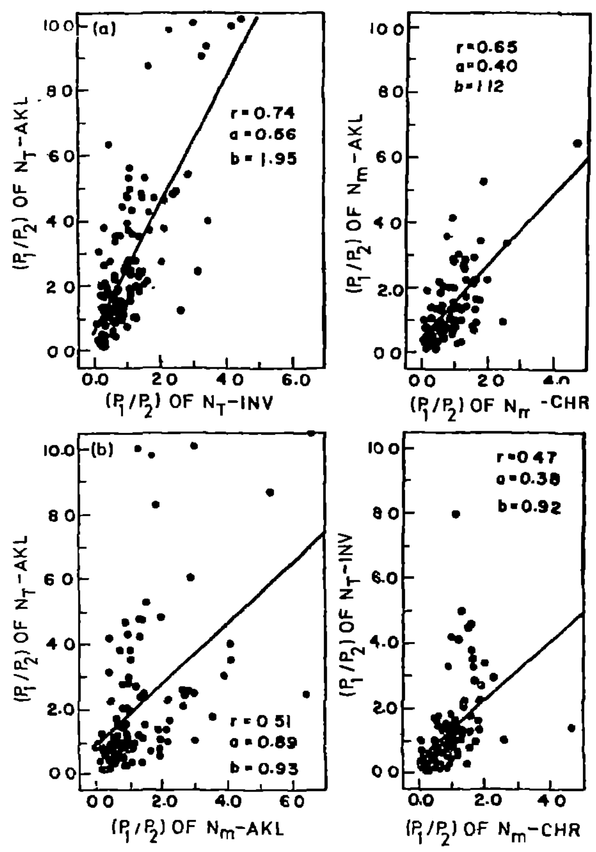

Fig. 3(a)—Mass plots of the ratio P_1/P_2 observed simultaneously in the diurnal variation of N_T at Auckland (AKL) and Invercargill (INV), of N_m F_2 at AKL and Christchurch (CHR), during summer months over the nine-year period from 1965-66 to 1973-74. [The parameters of the lines of best fit (a, b) and the correlation coefficients (r) are also shown]; (b) Same as on Fig. 3(a) but showing the simultaneous values of P_1/P_2 observed in the diurnal variation of N_T and N_m F_2 at AKL, of N_T at INV and N_m F_2 at CHR

at the lower midlatitude station, AKL, than at INV, i.e. the asymmetry in the bite-out is more marked at AKL. A similar behaviour is also noticed in N_m F_2. Secondly, in a few cases, the structure of the bite-out either in N_T or N_m F_2 is exactly opposite at the station-pairs considered, i.e. while at one station the forenoon maximum is prominent, the evening maximum is prominent at the other station. In fact, this behaviour is noticed in N_T in about 25% of the days and in N_m F_2 about 18% of the days on which the bite-out is simultaneously observed at the station-pairs considered. A typical example of this feature as noticed in N_T is illustrated in Fig. 4(a). From a careful examination of the data, it is further found that the occurrence of the bite-out either in N_T or N_m F_2 is not always simultaneous at the station-pairs considered. To give the statistical details in N_T, out of the 286 days at AKL and 261 days at INV when

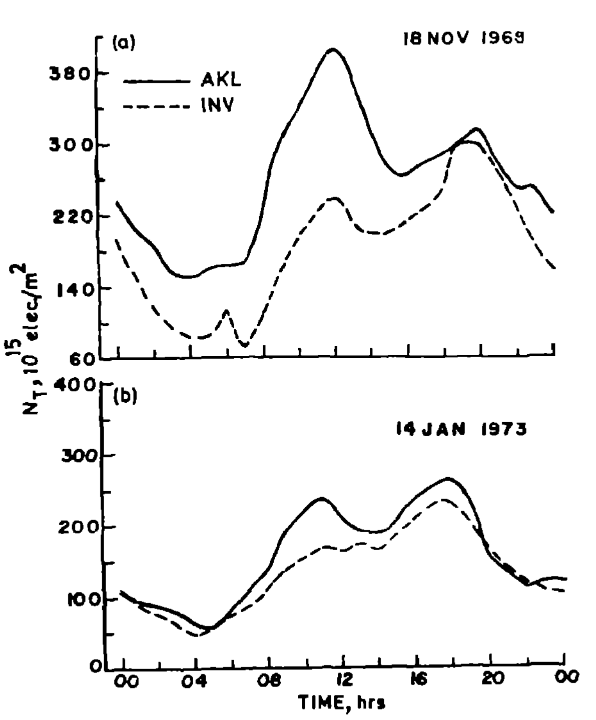

Fig. 4—(a) A typical example of the diurnal variation of N_T at Auckland and Invercargill showing opposite nature in the structure of the bite-out pattern at the two stations; (b) A typical example of the diurnal variation of N_T at Auckland and Invercargill showing the conspicuous absence of the bite-out at one of the two stations

the bite-out is observed, only on 129 days it is noticed simultaneously at these two stations. Similarly, in N_m F_2 out of the 194 days at AKL and 208 days at CHR when the bite-out is noticed, on only 95 days it is present simultaneously at both the stations. These values have been arrived at after excluding the days on which data were not available at one of the two stations. It is quite apparent that the lack of a simultaneous occurrence of the bite-out either in N_T or N_m F_2 at the pairs of stations is more frequent than the reverse situation A typical example that illustrates the conspicuous absence of the bite-out at one of the stations, as observed in N_T is presented in Fig. 4(b).

It was reported earlier that the diurnal variation of N_T and N_m F_2 at midlatitudes during summer is not always similar and that, on occasions the evening maximum in N_T is absent while it exists in N_m F_2 (Ref. 5). We have, therefore, examined this aspect using our extensive data. It is found that quite frequently there is a lack of a simultaneous occurrence of the bite-out in N_T and N_m F_2 both at AKL and INV. The most usual behaviour noticed on these occasions is the absence of the evening maximum in N_T. To quote the statistical figures at AKL, out of the 227 days in N_T and 225 days in N_m F_2 on which the bite-out is observed, only on 104 days it is observed simultaneously for both N_T and N_m F_2. Similarly, at INV, out of the 233 days in N_T and 262 days in N_m F_2 only on 122 days the bite-out is observed simultaneously. However, considering only those days for which the bite-out is simultaneously observed in N_T and N_m F_2 at any particular station, it is found that there exists a significant correlation ($P>0{\cdot}01$) of the changes in the structure of the bite-out in N_T and N_m F_2. This can be seen from the mass plots of P_1/P_2 shown in Fig. 3(b).

4. Discussion

A consideration of the results of the present study in the light of the findings of earlier studies[12,14,18-26] suggests a role of global atmospheric neutral air winds in the day-to-day variability of the bite-out in N_T and N_m F_2 at middle latitudes, as some of the features (viz. day-to-day changes in structure of the bite-out; variation of the average behaviour of the structure with the phase of the solar cycle; prominent bite-out effect at the lower midlatitude station, AKL; simultaneous occurrence of bite-out in N_T and N_m F_2 at any particular station, etc.) may be understood in terms of the effects of neutral air winds. It is, however, to be emphasized that the theoretical studies, so far made, paid particular attention to the behaviour of N_m F_2 and the effect of the changes in the phase of neutral air winds was studied only for sunspot minimum conditions. Extension of such studies to investigate the behaviour of N_T and for different solar activity conditions is required to substantiate the understanding reached here. Further, the results of the present study clearly indicate the involvement of physical processes besides the effects of neutral air winds, as some of the features (lack of simultaneous occurrence of bite-out in N_T and N_m F_2 at either AKL or INV; in N_T at AKL and INV and in N_m F_2 at AKL and CHR; opposite nature of the structure of the bite-out in N_T at AKL and INV, in N_m F_2 at AKL and CHR) cannot be accounted for just in terms of the effects of neutral air winds. The lack of a simultaneous occurrence of the bite-out in N_T and N_m F_2 (the usual behaviour is the absence of the evening peak in N_T) suggests that on these occasions, the evening peak in N_m F_2 could be due to a redistribution of the ionization as a result of the decrease in electron temperature at sunset, as suggested by some workers.[11,13,14] The mechanisms responsible for the other features are not apparent at the moment and need further detailed consideration.

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