Day-to-day Variability of Midlatitude F Region in Winter

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A study is made of the day-to-day variability of midlatitude F region during winter daytime conditions, using total electron content (TEC) measurements at Auckland (37·5°S; 175·0°E) and Invercargill (46·5°S; 168·4°E) and peak density measurements at Auckland and Christchurch (43·5°S; 172·8°E) covering the period June 1965-Dec. 1974. It is found that there exist significant positive correlations of mean daytime TEC and peak density at Auckland with auroral electrojet (AE) (and also K_p), with mean delays of 4 and 10 hr. There is also a significant positive correlation of mean daytime TEC at Invercargill with AE (and also K_p), with a delay of 4 hr. These features which are noticed consistently for several winters suggest a role of meridional neutral winds associated with perturbations of energy input into the auroral zones in the day-to-day variability of midlatitude F region.

Extensive information exists in the literature concerning the annual, semi-annual and seasonal variability of the ionospheric F region electron density and that associated with geomagnetic storms. In addition to these, the F region electron density exhibits variability on a day-to-day basis.[1-4] Further, significant perturbations in F region electron density are also known to occur, although occassionally, even under relatively quiet geomagnetic conditions.[5-7] The recent detailed case study made by us concerning significant depressions in midlatitude F region electron density under relatively quiet geomagnetic conditions (but found to be associated with auroral disturbances) indicated that they were due to changes in atmospheric neutral composition brought about by modifications in the global thermospheric circulation following heating in the auroral zones.[8] In this communication, we deal with the day-to-day variability of midlatitude total electron content (TEC) and peak density pertaining to winter daytime conditions and its dependence on geomagnetic (K_p) and auroral electrojet (AE) indices. The basic data used in this study were the hourly values of TEC measurements at the stations, Auckland (37·5°S; 175·0°E) and Invercargill (46·5°S; 168·4°E) using vhf transmissions from Syncom-3 and ATS-1 satellites, and peak density measurements of F2 region at the ionosonde stations, Auckland and Christchurch (43·5°S; 172·8°E). The study covers the period from June 1965 to Dec. 1974. As the objective is to undertake a statistical study of the day-to-day variability of daytime F region electron density, hourly values of

TEC and peak density at the stations mentioned above have been averaged over the time interval 1000—1500 hrs LT for each day. The analysis is restricted to winter months (May-Aug.) as an initial perusal of the diurnal plots of TEC and peak density showed that the day-to-day variability in the diurnal pattern of these two parameters is considerably less during winter compared with other seasons, for example, summer. It is, therefore, felt that the *daily mean values (1000—1500 hrs LT) of TEC and* peak density provide a more reliable measure of the day-to-day variability in the magnitude of daytime F region electron density during winter compared with other seasons.

The dependence of the day-to-day variability in TEC and peak density on K_p as well as AE is studied in the following way. For each day, the mean values of K_p and AE in the time intervals 0600—1100 and 0000—0600 hrs LT have been obtained. Cross-correlations of the daily mean values of both K_p and AE in the above-mentioned intervals with mean daytime TEC and peak density at the stations concerned have been evaluated with time shifts from —4 to +4 days. The correlations at zero time shifts between mean K_p or AE in the time intervals 0600—1100 and 0000—0500 hrs, and mean TEC (or peak density) in the time interval 1000—1500 hrs, therefore, corresponds to the duration of mean delay of 4 hr (short) and 10 hr (medium) respectively, between the preceding geomagnetic or auroral activity and the later ionospheric effect. The correlations at positive time shifts (in days) correspond to long delays, i.e. additional 24 hr or more to the basic delays mentioned depending on the shift. It is hoped that the evaluation of the delayed correlation of TEC and peak density to geomagnetic as well as auroral activity will help in an understanding of the physical processes responsible for the day-to-day variability. No distinction is made here between quiet and disturbed days, and all the data are used. A numerical filter of 15 days is used with the data to provide more reliable estimates of the correlation coefficients. Checks have been made to see whether any formally significant value of the correlation coefficient is due to the presence of a few extreme points in an otherwise uncorrelated data set through a recourse to scatter plots.

Fig. 1 shows the salient features of the correlograms (correlation coefficient corresponding to the peak) between the mean AE in the time intervals 0600—1100 and 0000—0500 hrs and mean daytime TEC as well as peak density for each winter from 1966 to 1971 and also for the winter months of the entire period 1966—1971. A similar representation of the correlation of K_p with TEC and peak density is

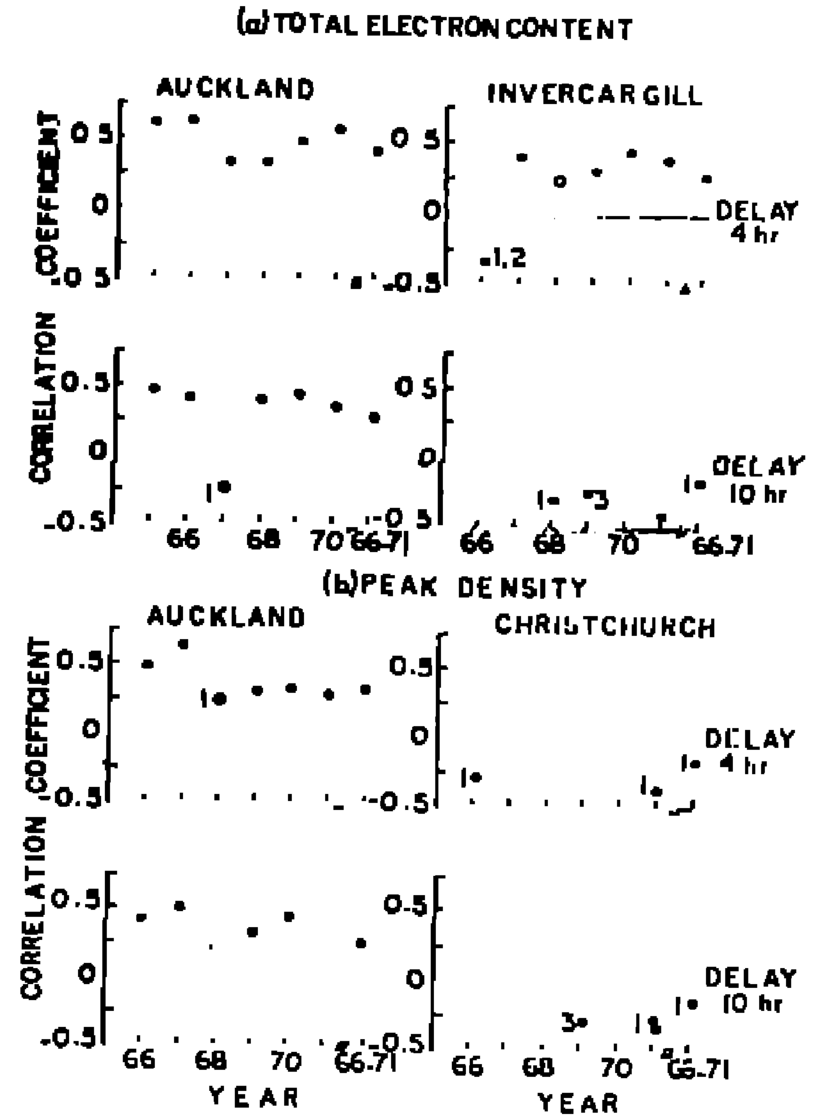

Fig. 1—Correlation of mean AE in the time intervals 0600—1100 and 0000—0500 hrs with mean daytime (a) TEC at Auckland and Invercargill (b) peak density at Auckland and Christchurch for each winter from 1966 to 1971 and for the winter months of the entire period 1966—71 [The number by the side of the plotted correlation coefficient indicates the lag in days (see text for further details)] (●, level of significance above 99%; ⊙, level of significance between 95% and 99%)

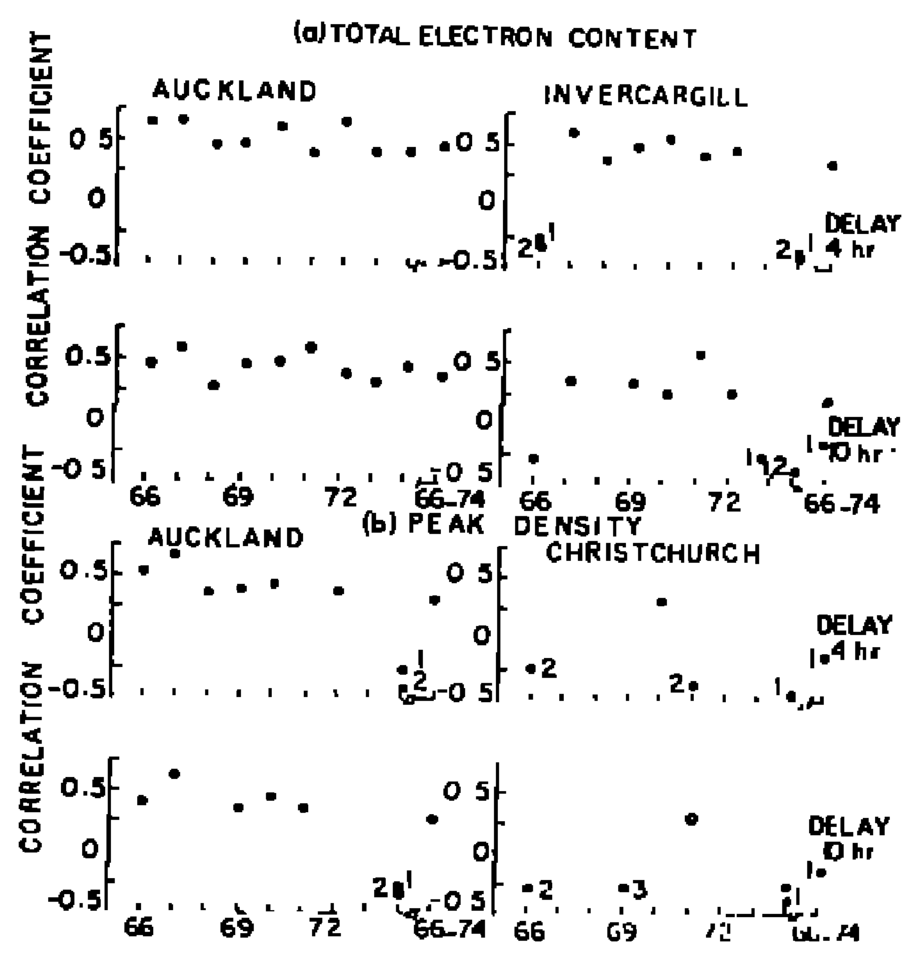

Fig. 2—Same as in Fig. 1 but showing the correlation of K_p for each winter from 1966 to 1974 and for the winter months of the entire period 1966—74

shown in Fig. 2 for the period 1966-74. Only those correlation coefficients that are significant at a confidence level above 95% are shown. The number by the side of the plotted correlation coefficient represents the lag in days (i.e. additional 24 hr or more to the basic delays depending on the lag) between the preceding AE or K_p and the later ionospheric effect. If a significant correlation is noticed at more than one particular time shift (broad peak), the corresponding time shifts are indicated. A glance at the results in Figs. 1 and 2 shows that the gross features of the correlation of TEC and peak density with AE are similar to those with K_p. A major exception to this is the difference in the nature of the correlation, corresponding to a delay of 10 hr of TEC at Invercargill with K_p and AE for some winters, although the overall trend is the same. The notable features of the results in Figs. 1 and 2 are as follows. At the lower midlatitude station, Auckland, both the TEC and peak density exhibit a significant positive correlation with AE as well as K_p with a delay of 4 and 10 hr. This behaviour is noticed consistently for several winters. On the other hand, the behaviour of TEC at Invercargill and in particular, that of peak density at Christchurch is less tidier. The rather consistent feature is the significant positive correlation of TEC at Invercargill with AE and K_p with a delay of 4 hr. In contrast, there is a less systematic dependence of peak density at Christchurch on AE and K_p, and the overall trend is a negative correlation with a long delay (greater than 24 hr). It is interesting to note that the positive correlation of both TEC and peak density with AE or K_p is always noticed with a delay of either 4 (short) or 10 hr (medium), and the negative correlation with a long delay of 28 hr or more.

The results of the present study show a convincing delayed correlation of midlatitude F region electron density during winter daytime conditions, particularly at Auckland, with AE and K_p indices. This suggests that the day-to-day variability may be due to perturbations of energy input with corresponding changes in atmospheric heating in the auroral zones. The observed positive correlation of daytime TEC and peak density at Auckland, and TEC at Invercargill with AE (and also K_p) suggests a role of meridional neutral winds in the day-to-day variability. An increase in auroral zone heating causes an enhancement of equatorward neutral wind which lifts the ionization relative to neutral gas to a region of lower loss rate thereby causing an increase in F region electron density.[9] This mechanism is more effective during daytime when photoionization is taking place. The effect of neutral winds may be expected at the midlatitude region of 35-45°, pertinent to this study, with a delay of about 1-6 hr based on the available observations[9-11] which show the neutral wind speed to lie in the range 200-400 m sec^{-1}. The temperature increase in the aurora zone, however, lags behind[12] the energy input by 6 hr although the recent observations indicate[13] the lag to be about 3 hr. Hence, neutral winds associated with increase in energy input in the auroral zone may be expected to effect the midlatitude F region with a delay in the range of 4-13 hr. It may be seen that the observed mean delay times of 4 and 10 hr are in correspondence with the expected delay times. The conspicuous absence of a systematic trend in the correlation of peak density at Christchurch with AE and K_p is quite interesting and needs further detailed consideration. It is to be emphasized that the nature of the statistical analysis attempted here does not permit an assessment of the possible role of eastward electric fields which can also cause an enhancement of F region electron density through vertical electrodynamic drifts (delay time ~ 1 hr).

In conclusion, the present work indicates that evaluation of the delayed effects of auroral and geomagnetic activity on midlatitude F region electron density leads to a slightly better understanding of the physical processes involved in the day-to-day variability of F region.

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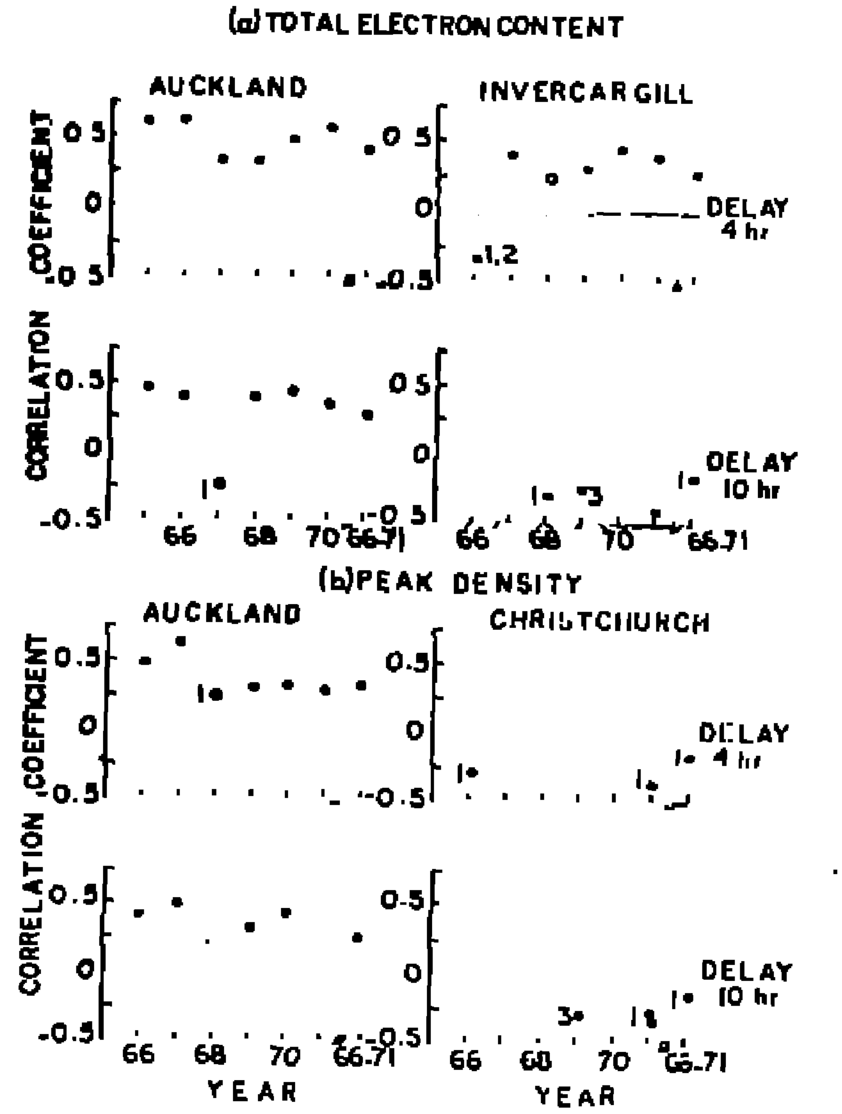

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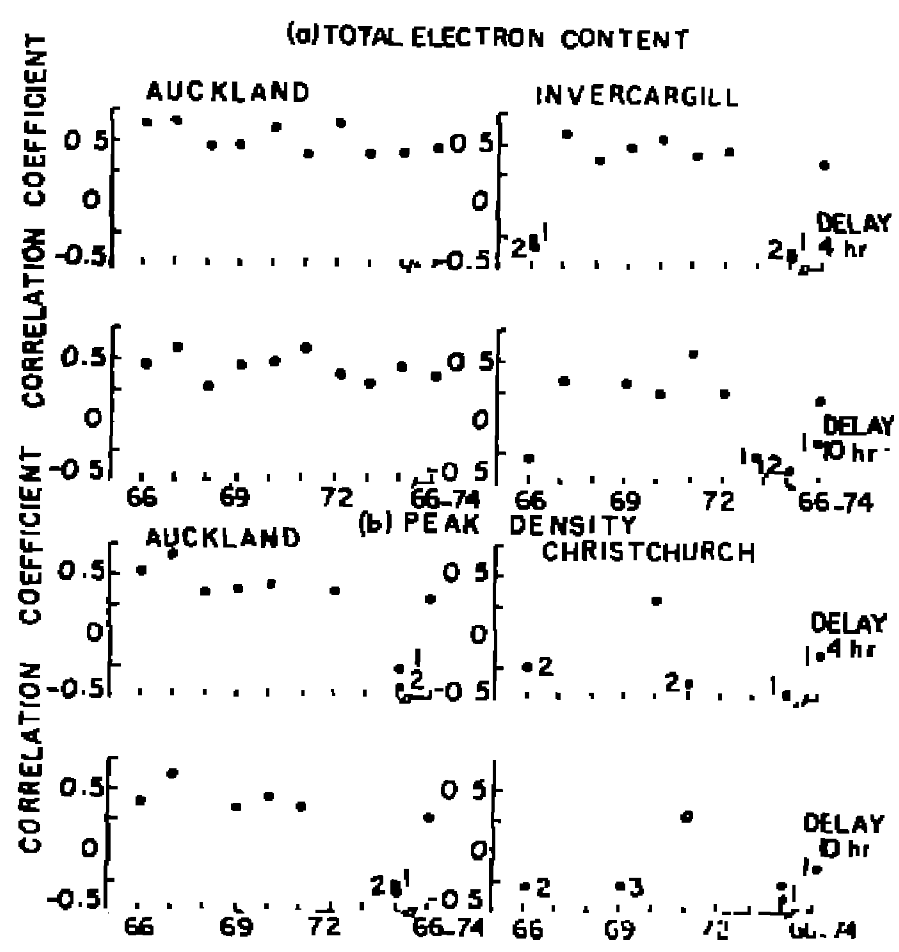

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