Variability of the time of peak occurrence in electron content at low latitudes

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A winter-to-summer delay in the occurrence of diurnal peak in total ionospheric electron content (IEC) was observed at Indian and Pacific equatorial and low latitude stations. The time delay exhibits latitudinal variation with a minimum near the crest of the 'equatorial anomaly'. A comparison with the data from American near-equatorial stations showed that the time delay is reversed from summer to winter indicating a longitudinal asymmetry between Asian and American sectors.

The time at which total ionospheric electron content (IEC) attains its maximum value varies from one day to another or with season. De Mendonca et al. found that, in summer, the time of peak occurrence was advanced by an hour as compared to that in winter. In the Indian zone, daytime maximum in summer was found to be delayed by at least half an hour with respect to that in winter at Patiala and Delhi. Contrarily, no appreciable shift in the time of peak occurrence from winter to summer had been reported from midlatitude under varying solar activity conditions. In a recent communication, we have reported that IEC tends to reach its daytime maximum late in the day with the increase in solar activity at equatorial and low latitude locations which are normally situated away from the crest region of the 'equatorial anomaly', whereas no such retardation was observed at the crest region. Progressive retardation in the time of peak occurrence in IEC with increase in solar activity at Lunping, a low latitude station, had been reported earlier. The present report is an extension of our earlier efforts in search of a possible causative factor which might be responsible for the observed variability in the time of occurrence of the diurnal peak in IEC.

In Fig. 1, the times of occurrence of the daytime maximum in electron content averaged for each month from October 1975 to July 1976 are plotted for seven Indian locations. Selected stations form a latitudinal chain along the 71(±2)'E meridian as detailed in Table 1. Figure 1 indicates that the peak occurs earlier in winter and later in summer at all the locations. The winter-to-summer average time delay is minimum at Bombay (40 min) and maximum at Patiala (105 min). The average occurrence times of the diurnal peak in the two seasons and the corresponding time delays are given in Table 1 for all these locations. Table 1 also indicates that the delay increases towards tropical and equatorial latitudes from the observed minimum at Bombay. The latitudinal variation in time delay is not caused by random variations in the time of peak occurrence. In summer, electron content maximum was observed at about the same time (15 ± 0.5 hrs L T; Table 1),

Fig. 1—Average time of peak occurrence of IEC plotted as function of month for stations around 71°E meridian for the period October 1975-July 1976.
Table 1—Average time of occurrence of $IEC_{\text{max}}$

<table>
<thead>
<tr>
<th>Station</th>
<th>Subionospheric coordinates</th>
<th>Time of $IEC_{\text{max}}$ (hrs LT) in</th>
<th>Time delay min</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lat., °N</td>
<td>Long., °E</td>
<td>Summer</td>
</tr>
<tr>
<td>Thumba</td>
<td>9.9</td>
<td>73.3</td>
<td>1530</td>
</tr>
<tr>
<td>Ootacamund</td>
<td>11.0</td>
<td>73.5</td>
<td>1500</td>
</tr>
<tr>
<td>Bombay</td>
<td>17.8</td>
<td>69.8</td>
<td>1455</td>
</tr>
<tr>
<td>Ahmedabad</td>
<td>21.5</td>
<td>69.4</td>
<td>1500</td>
</tr>
<tr>
<td>Udaipur</td>
<td>22.6</td>
<td>69.6</td>
<td>1440</td>
</tr>
<tr>
<td>Gauhati</td>
<td>23.8</td>
<td>83.6</td>
<td>1550</td>
</tr>
<tr>
<td>Lunping</td>
<td>22.7</td>
<td>129.5</td>
<td>1430</td>
</tr>
<tr>
<td>Delhi</td>
<td>26.2</td>
<td>72.2</td>
<td>1430</td>
</tr>
<tr>
<td>Patiala</td>
<td>28.3</td>
<td>72.1</td>
<td>1430</td>
</tr>
</tbody>
</table>

whereas the time of peak occurrence in winter varied from place to place. In the equinoxes, daytime maximum occurs at a time which is later than that in winter and earlier to that in summer. An annual variation is, therefore, observed in the hour of peak occurrence in electron content. Figure 2(a) shows the time of peak occurrence as plotted in Fig. 1 for Delhi for the high sunspot activity period of May 1978-April 1979 (mean $R = 111.2$). It may be seen that $IEC$ peaks later in summer than in winter for this period of high activity too. The seasonal variation in the time of peak occurrence is, therefore, annual and independent of solar activity conditions.

To examine the validity of the observed seasonal variation at other longitude sectors, the time of $IEC_{\text{max}}$ has been plotted in Fig. 2 (b) for three stations which form a longitudinal chain along 23°N extending from the Indian to the Pacific sector. It could be noted that the seasonal variation in the time of peak occurrence is similar at the locations, Gauhati and Lunping. However, the seasonal variation observed in the Asian zone may not be typical of other longitude zones, as variations in the structure of the 'equatorial anomaly' in different longitude sectors are well known.

The dominant mechanism controlling the $IEC$ in the equatorial and low latitudes is the $E \times B$ drifts. Diurnal and seasonal variations in $F$-region drifts over Jicamarca, Peru (12°S; 77°W; mag. dip. 2°N) have been reported by Woodman et al. and Fejer et al. When the daytime maxima in $F$-region vertical drifts during different seasons were compared, a time difference of more than 1 hr from summer (~ 1000 hrs LT) to winter (~ 1100 hrs LT) was observed. This was further confirmed from reported $f_0 F2$ observations at Huancayo, Peru (12°S; 75°W; mag. dip. 2°N). The $f_0 F2$ over Huancayo peaks at about 1530 hrs LT in summer and at 1730 hrs LT in winter. There is, therefore, a reversal in the seasonal time delay between the Asian and American sectors. Fejer had shown that the vertical drift reversal times in the Peruvian and Indian equatorial regions have similar annual variation with a six-month shift between the two. The magnetic equator is ~9°N of the geographic equator in the Asian region (75°E and 120°E), while it is ~12°W of the geographic equator in the American region (75°W). The reason for this shift is probably the location of Peruvian and Indian stations in the southern and northern hemispheres, respectively. Another possible reason for the observed longitudinal differences in equatorial anomaly structure between the Asian and American sectors is the different location of the sub-solar points with
respect to the magnetic equator\textsuperscript{11}. Orientation of the magnetic field lines also may have a role to play in bringing about the observed longitudinal asymmetry.

During solar minimum, ‘winter anomaly’ in IEC was observed only at locations situated within the equatorward trough of the ‘equatorial anomaly’\textsuperscript{2,5}. Movement of ionization from summer to winter hemisphere is believed\textsuperscript{5-12} to be one of the reasons for the F-region ‘winter anomaly’. The magnetic field lines corresponding to F-region heights at the low latitude stations, Ootacumund and Bombay, cross the equator at heights of \(\sim 300\) km and \(\sim 600\) km, respectively, whereas ionization which produces the ‘equatorial anomaly’ under the effect of \(E \times B\) fields rises up to \(\sim 900\) km above the equator before its descent along magnetic field lines to form the crest of the anomaly at tropical latitudes northward of Bombay. Thus during solar minimum, the inter-hemispheric transport of ionization should take place along the field lines confined only to lower heights to effectively produce maximum in ionization at the low latitude stations earlier in winter than in summer. In summer, the sub-solar point at midday is about 15° dip lat. over the Asian zone and maximum ionization occurs under the influence of the sun at about the same local time in all the locations in the Indian and Pacific regions. However, in winter, two separate processes, namely, sun’s declination and inter-hemispheric transport, are effective; and peak ionization takes place at different times at different locations giving rise to the observed variations in the time delay between winter and summer peak occurrences.

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References