CHAPTER III

Measurement of horizontal drifts in the E region over Ahmedabad from September 1956 to February 1962

The total period of observations on E and F region drifts are divided in two parts, since the results on drift speed and direction differ in some respects in the two groups. Thus we shall consider the following two periods separately:

(1) September 1956 to February 1959
(2) November 1959 to February 1962.

In each of these periods, the data were analysed separately for the E and F regions. We shall first present the results for the E region and in the next chapter we shall do for the F region.

To study the seasonal variation in drift speed and direction the data were grouped according to season, equinoxes (March, April, September and October), summer (May, June, July and August) and winter (November, December, January and February). In each of these seasons, the diurnal variation of drift speed and direction was also studied. It was generally found that there was no significant difference between the changes in speed or direction in the same season of the different years in each period and hence combined histograms for each season were prepared for each of the two periods (1) and (2). A similar
procedure of grouping the data was adopted to study the diurnal variation of drift speed and its components along E-W and N-S directions.

The total number of observations (No) used in the preparation of the histograms and so also the arithmetic mean $\bar{V}$ and the median value $V^\text{X}$ of the drift speed are shown on the appropriate diagrams.

Results of analysis of horizontal drifts in the E region

1. Mean annual variation in speed and direction at 2.6 Mc/s during day and night

(1) 1956-59

Figure 3.1(a) shows histograms of the percentage occurrence of drift speed and direction for night and day. During night, the most frequent values of speed lie between 60 and 80 m/s with mean and median value 85 m/s and 74 m/s respectively. During day the most frequent values lie in the range 40-60 m/s with mean and median at 79 m/s and 68 m/s respectively. This shows that the average speed is higher during night than during day. The histograms show sharp rise and slow fall in frequency of occurrence of different speeds with a peak between 20 and 140 m/s.

The histograms of drift directions show two peaks, one towards N-W and the other towards S-E. The former appears to be more prominent than the latter. However the nighttime
Figure 5.1 Histograms showing annual mean variation of E region drift speed and direction on 2.6 Mc/s during day and during night.

(a) - 1956-59

(b) - 1959-62
histograms show comparatively larger percentage of occurrence towards north or east.

(ii) 1959-62

Figure 3.1(b) shows the histograms of percentage occurrence of drift speed and direction for night and day during 1959-62. The histograms for drift speed show sharp rise and sharp fall with most frequent occurrences in the range 40-60 m/s. The mean speed is 73 m/s during night and 62 m/s during day.

The drift direction shows a single maximum towards S-E during night. In daytime the direction is not so well defined but in the majority of cases it is towards N-W or S-E.

2. Drift speed and direction at 4.0-4.4 Mc/s

On some occasions reflections on 4.0-4.4 Mc/s were obtained from sporadic E during daytime. A comparison is made in Figure 3.2 of the results obtained on 2.6 Mc/s and 4.0-4.4 Mc/s reflections from E region during day. Apart from small differences in speed and direction at the two frequencies the general features are not significantly different.

3. Seasonal variation

(i) Drift speeds 1956-62

To study the seasonal variations in speed and direction
Figure 3.2 Histograms showing annual mean variation of E and/or Eₘ region drift speed and direction on 2.6 and 4.0-4.4 Mc/s during daytime.

1956-59

of daytime and nighttime drifts histograms were constructed for three seasons, equinoxes, winter and summer. These are shown in Figure 3.3(a) for 1956-59 and in Figure 3.3(b) for 1959-62. In all seasons the histograms for daytime speeds show rapid rise and gradual fall with maximum occurrence in the range 40-60 m/s. The nighttime histograms show a more gradual rise and the peak is shifted to the range 60-80 m/s.
Figure 3.3 Histograms showing seasonal variation of E region drift speed on 2.6 Mc/s.
The findings are summarised in Table 3.1 for the entire period 1956-62. It may be seen that seasonwise, the average speed is maximum in winter and minimum in equinoxes except during daytime in 1959-62 where the minimum speed is found in summer. Diurnally the average speed is higher during night than during day in all seasons.

Table 3.1

Average value of drift speeds in the E region for daytime and nighttime hours in different seasons of the years (1956-59) and (1959-62).

<table>
<thead>
<tr>
<th>Season</th>
<th>1956-59</th>
<th>1959-62</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Night</td>
<td>Day</td>
</tr>
<tr>
<td></td>
<td>m/s</td>
<td>m/s</td>
</tr>
<tr>
<td>Equinoxes</td>
<td>77 ± 5</td>
<td>69 ± 2</td>
</tr>
<tr>
<td>Winter</td>
<td>94 ± 10</td>
<td>88 ± 2</td>
</tr>
<tr>
<td>Summer</td>
<td>88 ± 4</td>
<td>75 ± 2</td>
</tr>
<tr>
<td>Annual Mean</td>
<td>85 ± 3</td>
<td>79 ± 1</td>
</tr>
</tbody>
</table>

(ii) Drift direction 1956-62

The histograms of occurrence of drift directions are shown in Figure 3.4(a) for 1956-59. The frequency of occurrence is distributed nearly equally towards S-E and N-W during daytime in equinoxes and summer, while in winter it is more towards N-W
than towards S-E. Reverse is the case for nighttime except in summer when it is more towards N-W.

Figure 3.4 Histograms showing seasonal variation of E region drift direction on 2.6 Mc/s.
Figure 3.4(b) shows the results for 1959-62. Here the peak towards S-E is very prominent during night in all seasons. The daytime directions are very variable, but there is a tendency towards S-E in summer and towards N-W in winter.

4. Mean hourly variation in drift speed

To obtain average hourly variation in drift speed, the hourly values of speeds were averaged for all days in each season as well as for the whole year to get the annual average curve. These curves are shown in Figure 3.5(a) and Figure 3.5(b). The open circles indicate that the number of observations in that hourly interval were few. A clear diurnal variation appears in summer with a maximum at midnight and a minimum at midday; in winter of 1959-62, a weak semidiurnal variation is observed. During equinoxes and winter the nighttime values show large scatter. The yearly average curve shows a diurnal variation with a maximum between 22 and 04 hours and a flat minimum during day.

To find the diurnal variation in drift direction, histograms were prepared for 06-07 hrs, 08-10 hrs, 11-13 hrs, 14-15 hrs and 16-18 hrs. We had to resort to this sort of grouping because of fewer number of observations at one particular time. The results for 1956-59 are shown in Figure 3.6(a). No histograms are shown for 11-13 hrs and 14-15 hrs in summer and equinoxes and for nighttime in any season since sufficient data do not exist. The figures show
Figure 3.5 Curves showing diurnal variation of average drift speed in the E region.

(a) - 1956-59

(b) - 1959-62
Figure 3.6 Histograms showing the variation of E region drift direction for few hours during day.

(a) - 1956-59

(b) - 1959-62
a strong peak in the N-W direction during daytime in winter
and a small secondary peak in the S-E direction in the early
morning hours (06-07 hr). In summer and equinoxes, N-W and
S-E directions are equally probable in the forenoon hours but
change towards N-W in the afternoon hours.

Figure 3.6(b) shows the results for 1959-62. The
prevailing directions are S-E in summer and N-W in winter.
The scatter is very large at 16-18 hrs in all seasons and at
06-07 hrs in winter. During equinoxes, the predominant direction
changes from S-E in the forenoon hours to N-W in the afternoon
hours.

5. **Diurnal variation of E-W and N-S components of drift**

The components of drift velocity along E-W and N-S
directions (positive towards north and towards east) were
obtained and the average diurnal variation of the E-W and N-S component
was averaged for each season and for the whole year. These
curves are shown in Figure 3.7(a) and Figure 3.7(b). As before
open circles in the figure are based on few observations. An
inspection of these curves shows:

(1) **During 1956-59 - Figure 3.7(a)**

The E-W component is generally towards west during
most of the day, except early morning when the drift is
eastwards. The N-S component is generally towards north except
for few hours in the morning and late evening.
Figure 3.7 Curves showing diurnal variation of E-W and N-S components of E region drifts.

(a) - 1956-59

(b) - 1959-62
(ii) During 1959-62 - Figure 3.7(b)

The E-W component is generally towards west during daytime and towards east during nighttime and the N-S component towards north during day and south during night in winter and equinoxes. In summer the E-W component is towards east and the N-S component towards south at all hours of the day.


We have attempted here to present the results of harmonic analysis of individual curves shown in Figure 3.7(b). We obtained the diurnal and semidiurnal vectors in the E-W and the N-S components from the following well known relation:

\[ V = V_0 + V_1 \sin(t + \theta_1) + V_2 \sin(2t + \theta_2) \]  

where \( V_0 \) is the amplitude of steady component, \( V_1, \theta_1 \) and \( V_2, \theta_2 \) are the amplitudes and phases of the 24 hr and 12 hr waves. The results are given in Table 3.2 and are shown on harmonic dials in Figure 3.8. It can be seen that the diurnal component is in general more prominent than the steady or the semidiurnal component except in summer.

The same results are shown in polar plots in Figure 3.9. Here it can be seen that the steady vector is prominent towards S-E in summer and in equinoxes, but changes to S-W in winter. The diurnal vector traces an ellipse of high
Table 3.2

Coefficients of harmonic analysis of E region drifts during 1959 to 1962

<table>
<thead>
<tr>
<th>Season</th>
<th>Steady Component</th>
<th>Diurnal Component</th>
<th>Semidiurnal Component</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>E-W drift</td>
<td>N-S drift</td>
<td>E-W drift</td>
</tr>
<tr>
<td></td>
<td>$V_0$ m/s</td>
<td>$V_0$ m/s</td>
<td>$V_1$ m/s</td>
</tr>
<tr>
<td>Equinoxes</td>
<td>+19.5</td>
<td>-15.2</td>
<td>25.0</td>
</tr>
<tr>
<td>Winter</td>
<td>-9.1</td>
<td>-5.4</td>
<td>31.1</td>
</tr>
<tr>
<td>Summer</td>
<td>+27.2</td>
<td>-25.6</td>
<td>4.1</td>
</tr>
<tr>
<td>Annual Mean</td>
<td>+12.5</td>
<td>-15.5</td>
<td>18.6</td>
</tr>
</tbody>
</table>

Positive sign refers to direction towards east & negative sign towards west in E-W component.
Positive sign refers to direction towards north & negative sign towards south in N-S component.
$V_1$, $\theta_1$, and $V_2$, $\theta_2$ refer to the amplitude and phase at which maximum eastward or northward drift is observed, according to the equation:

$$V = V_0 + V_1 \sin (t + \theta_1) + V_2 \sin (2t + \theta_2)$$
Figure 3.3 Harmonic dial of E-W and N-S drift vectors in the E region, where magnitude and time of maximum amplitude are plotted.
Figure 3.9  Polar plots of steady, diurnal and semidiurnal drift vectors in the E region.
eccentricity and rotates anticlockwise in winter and equinoxes, but clockwise in summer.

In the case of the semidiurnal component, its vector also traces an ellipse with a sense of rotation in a clockwise direction in winter and in summer but in anticlockwise direction in equinoxes. The amplitude of the diurnal and semidiurnal vector is maximum in winter but minimum in summer.

7. Discussion

Summarising all the available data up to 1953 from the high latitude stations, Briggs and Spencer (1954) report that 80 m/s could be taken as a representative value for the drift speed in the E region and that it is higher in winter than in summer. Later papers on the subject /Tsukamoto and Ogata (1959), Mitra et al (1960), Rao and Rao (1961), Piggott and Barclay (1962)/ show the results at Yamagawa, Delhi, Waltair and Halley Bay for the IGY period. All these stations except Waltair showed higher winter drift speeds. At Waltair, Rao and Rao (1961) did not find any significant variation in the drift speed. The most probable value of the speed ranged from 89 m/s at Yamagawa, 83 m/s at Waltair, 65 m/s at Halley Bay to 55 m/s at Delhi. At Ahmedabad during the same period the most frequent value of drift speed was about 82 m/s. This shows that at Delhi the speed was minimum.

Rao and Rao (1965) have analysed the drift data of Waltair, Yamagawa, De Bilt, Brisbane and Wellington for the
period 1958 and they find that the most probable range of drift speed is 60-80 m/s except at Brisbane where it is only 20-40 m/s. Their analysis also shows that at all the stations they studied, the nighttime average drift speed is higher than during day and that the difference between nighttime and daytime speed was higher at Yamagawa than at any other place. Our results at Ahmedabad are consistent with the above findings as we have seen earlier that the average speed here is 85 m/s during night and 79 m/s during day.

Latitudinally, we find that the most probable drift speed is minimum at Delhi and Ahmedabad and increases towards equator and high latitudes. A summary of the results at different places is given in Table 3.3.

Table 3.3
Comparison of drift speeds in the E region of the ionosphere at different places

<table>
<thead>
<tr>
<th>Station</th>
<th>Geomag. lat.</th>
<th>Most probable range of speed</th>
<th>Mean Speed</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waltair</td>
<td>7°N</td>
<td>60-80 m/s</td>
<td>61 m/s</td>
<td>Rao &amp; Rao (1965)</td>
</tr>
<tr>
<td>Ahmedabad</td>
<td>14°N</td>
<td>40-60 m/s</td>
<td>76 m/s</td>
<td>Patel (present thesis)</td>
</tr>
<tr>
<td>Delhi</td>
<td>19°N</td>
<td>50-60 m/s</td>
<td>73 m/s</td>
<td>Mitra et al (1960)</td>
</tr>
<tr>
<td>Yamagawa</td>
<td>20°N</td>
<td>60-80 m/s</td>
<td>73 m/s</td>
<td>Rao &amp; Rao (1965)</td>
</tr>
<tr>
<td>De Bilt</td>
<td>59°N</td>
<td>60-80 m/s</td>
<td>90 m/s</td>
<td>Rao &amp; Rao (1965)</td>
</tr>
<tr>
<td>Brisbane</td>
<td>36°S</td>
<td>20-40 m/s</td>
<td>51 m/s</td>
<td>Rao &amp; Rao (1965)</td>
</tr>
<tr>
<td>Wellington</td>
<td>52°S</td>
<td>60-80 m/s</td>
<td>78 m/s</td>
<td>Rao &amp; Rao (1965)</td>
</tr>
</tbody>
</table>
The mean hourly values of drift speed when plotted with the time of the day do not show any significant periodicity in any season except at Waltair where a semidiurnal trend is seen (Rao and Rao, 1965). Such a plot for Ahmedabad shows only diurnal variation in summer but no significant periodicity in other seasons. This means that there is diurnal or semidiurnal variation in some seasons at low latitude stations like Ahmedabad and Waltair but no clear periodicity at high latitude stations.

Comparison of E region drifts during 1956-59 and 1959-62 at Ahmedabad

Comparing the results at Ahmedabad from 1956 through 1962 we find that the average drift speed has decreased both during day and during night with decrease in sunspot activity. This is in agreement with that reported by Rao and Rao (1964) at Waltair.

The average drift speed shows seasonal variation during both the periods with maximum in winter and minimum in equinoxes for nighttime observations. During daytime it is maximum in winter; the minimum is in equinoxes during 1956-59 and in summer during 1960-62.

The diurnal variation of average speed during 1956-59 shows 24 hourly variation in summer and no significant diurnal or semidiurnal variation in winter and equinoxes. However during 1959-62 there is diurnal and weak semidiurnal change
in summer and in winter respectively and no clear periodicity in equinoxes. This may be regarded as a variation with solar activity.

8. Summary and conclusions

We may draw the following conclusions from the study of E region drifts:

(1) There is no significant difference between the speed and the direction of the drift measured on 2.6 Mc/s and 4.0-4.4 Mc/s.

(2) The average drift speed is about 80 m/s and is maximum in winter and minimum in equinoxes except during daytime in 1959-62; and is higher during night than during day.

(3) In 1956-59 most probable direction is towards N-W in winter daytime and summer nighttime. In other seasons the N-W and S-E directions occur equally frequently. In 1959-62 the most probable direction is towards S-E during nighttime. During daytime the most probable direction is towards N-W in winter and towards S-E in summer. In equinoxes, the majority of the directions occur towards N-W and S-E in daytime.

(4) There is no diurnal variation in drift speed in winter and equinoxes, but we find a diurnal variation with minimum around noon and maximum around midnight in summer and semidiurnal variation in winter during 1959-62.
(5) In general, the E-W component is more towards west and the N-S component more towards north during day, and towards east and towards south during night. In summer of 1959-62, the E-W component, towards east all the time and N-S component is towards south all the time.

(6) From the harmonic analysis it appears that the diurnal variation of drift is more prominent than the steady or the semidiurnal wave except in summer when the steady vector predominates.

(7) The rotation of diurnal drift vector with time is anticlockwise in winter and equinoxes, but clockwise in summer.

(8) The rotation of semidiurnal drift vector with time is clockwise in winter and summer, but anticlockwise in equinoxes.