COMPARISON OF IONOSPHERIC DRIFTS OVER THUMBA BY THE METHOD OF SIMILAR FADES AND CORRELATION METHOD

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Received July 3, 1967

(Communicated by Professor K. R. Ramanathan, F.A.SC.)

Regular ionospheric drift measurements at Thumba (Geog. lat. 8·5° N, Geog. long. 76·9° E) near the magnetic equator, using the spaced receiver technique, have been made since January 1964. The frequency of radio waves used was 2·2 Mc/s. for the E region reflections, and 4·7 Mc/s. for F region reflections. The period studied in this article comprises January to December 1964. The results obtained using the similar-fade method of analysis have been reported in earlier papers (Rastogi *et al.*, 1966 and Deshpande and Rastogi, 1966). The most important results have been that the drift directions are predominantly towards the West and the drift speeds higher than at any other station in the world. The amplitude fading records at the North-South pair of aerials are very similar in appearance and there is little time shift between them. It was felt that the extremely small time shifts between individual fades at N–S pair of aerials might produce a personal bias in the determination of drift direction. Hence a number of records were subjected to correlation analysis and the results of speed and direction so obtained are compared with those obtained by similar-fades analysis using the same set of observations.

Figure 1 shows sample fading records of E and F region reflections and the antenna set-up used for the observations. The first and second fading records, *i.e.*, for 2 August and 6 July 1964 are typical of the most frequently occurring patterns in which the time delays from one fade to another show consistency. The third fading record, *i.e.*, for 7 July 1964 is a fast fading sample in which the similarity between the fades still exists. The fourth record, *i.e.*, for 1 August 1964 is one in which the time delays of peaks are variable. This type of record is rather rare. The similar-fades analysis consists in finding the mean time shifts of individual peaks or troughs of

signal intensity at pairs of antenna and the speed and direction are given by equations

$$\frac{1}{V^2} = \frac{4}{d^2}\left[\bar{T}_x^2/\bar{T}_y^2\right] \tag{1}$$

$$\theta = \tan^{-1}\left[\bar{T}_y/\bar{T}_x\right] \tag{2}$$

where $\bar{T}_x$ and $\bar{T}_y$ are the mean time shifts in the records of E–W and N–S pairs of aerials respectively, d is the distance in meters between the aerials, and θ is the direction of drift measured clockwise from north.

In the cross-correlation method of analysis, the correlation coefficients of the amplitudes in pairs of fading records are determined for a series of varying time shifts between them. The time shift giving the maximum cross correlation is taken to give the best value of $\bar{T}_x$ and $\bar{T}_y$ and these are used in Equations (1) and (2). Figure 2 shows the cross-correlograms between E–W aerials (ρ_{CE}) and between N–S aerials (ρ_{CN}) for the four fading records of Fig. 1. The time shift of the peak value of ρ is determined graphically.

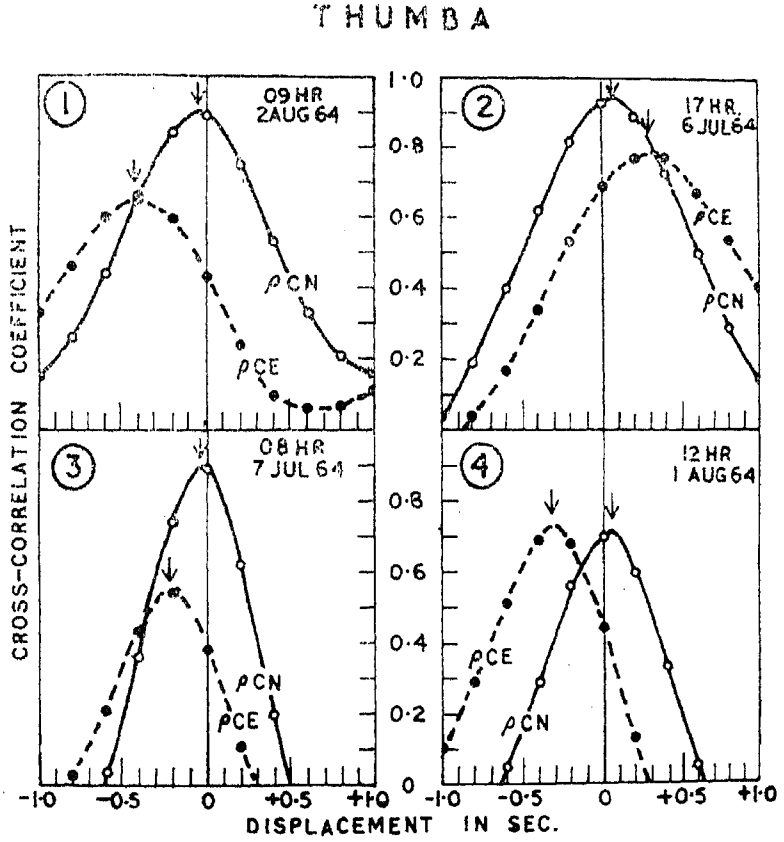

FIG. 2. The correlograms at pairs of North-South (ρ_{CN}) and East-West (ρ_{CE}) antennas, of the fading records given in Fig. 1. The time displacement of peak correlations are indicated by arrows.

The values of drift speed and direction for these rocords were calculated by the method of similar-fades and the method of optimum correlation and the results are given in Table I. It is seen that the differences between the results are not significantly different.

TABLE I

The drift speeds and directions as determined by the similar fades (S) and peak correlation (X) methods

Date	Drift speed m/sec.		Drift direction	
	Method S	Method X	Method S	Method X
2nd August 1964 ...	140	145	257°	262°
6th July 1964 ..	163	196	77°	81°
7th July 1964 ..	253	268	270°	259°
1st August 1964 ..	176	184	270°	281°

The fading records obtained during daytime on five days in a month were randomly selected and these were subjected to both kinds of analysis. About 400 records each of the E and F region reflections were analysed.

In Fig. 3 are shown mass plots of E and F region drift values to show the relation between the values determined by the two methods. It is seen that the points lie fairly close to a straight line making an angle of 45° with the axes, indicating that there is no consistent difference between the results from the two methods. There is however a slight scatter of points for drift speeds above 300 m/sec. which may be due to the very small time shifts in these cases.

In Fig. 4 are shown histograms for E and F region drift speeds for different seasons as calculated by the method of similar fades and optimum correlation method. The histograms of V′ by the two methods are almost identical except for the E region during equinoxes when the peak value of occurrence is slightly shifted.

In Table II, a statistical comparison is made between the two methods. The median value of the drift speed is always greater than the corresponding

TABLE II

The median (V'^*), lower quartile (Q_1), upper quartile (Q_3), mean ($\bar{V}'$) and standard deviation of the sample ($\sigma_{V'}$), the standard error of the mean ($\sigma_{\bar{V}'}$), of the drift speeds in the E and F regions of the ionosphere over Thumba as calculated by similar fades method (S) and by cross-correlation method (X) separately

	Winter		Equinox		Summer		Winter		Equinox		Summer	
	Method S	Method X	Method S	Method X	Method S	Method X	Method S	Method X	Method S	Method X	Method S	Method X
Median (V')*	141	134	140	146	120	120	123	121	183	174	138	148
Lower quartile (Q_1)	90	90	105	113	87	88	74	70	125	100	98	97
Upper quartile (Q_3)	201	187	173	225	156	166	171	168	260	267	211	200
Mean ($\bar{V}'$)	150	151	161	166	137	131	130	127	200	191	161	161
Standard deviation of the sample ($\sigma_{V'}$)	69	71	63	73	66	65	65	72	79	87	76	69
Standard error of the mean ($\sigma_{\bar{V}'}$)	5	5	6	7	5	5	7	8	8	9	6	6

All values are in m/sec.

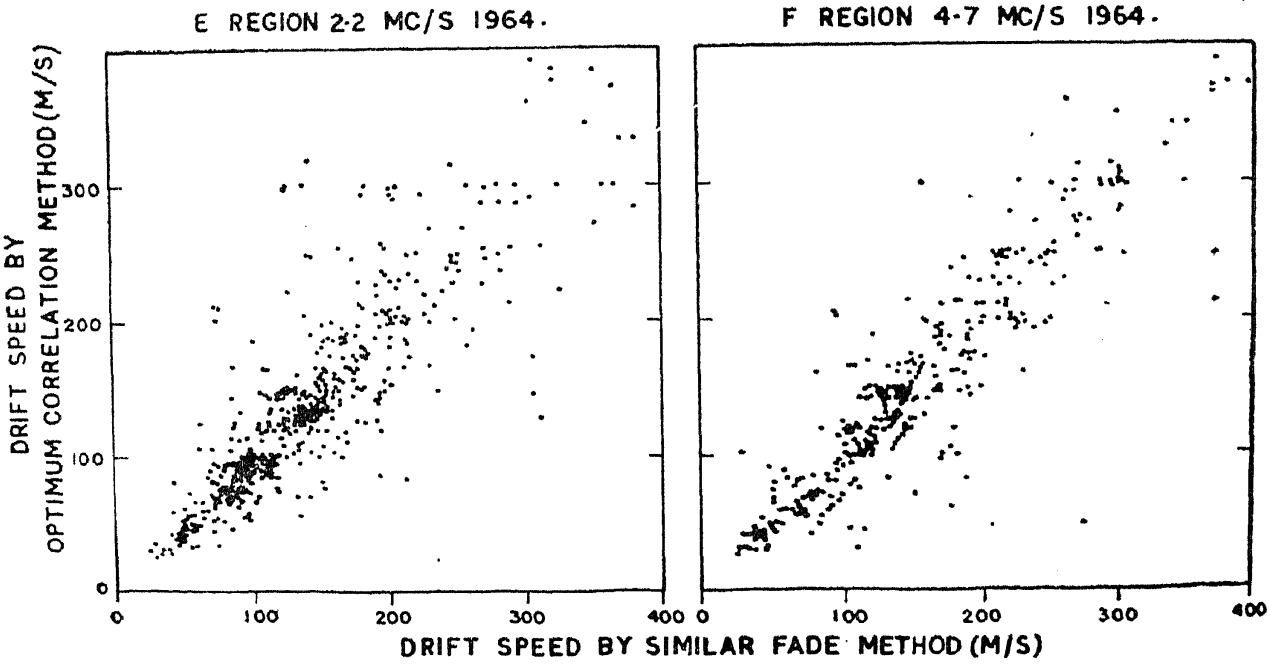

FIG. 3. Comparison of drift speeds calculated by similar fades and optimum cross-correlation method.

mean value indicating that the distributions are skewed towards higher values as can be seen from Fig. 4. The difference between the mean and median values range between 6 to 23 m/sec. The mean or median value determined by the two methods in any season is almost the same, the difference being less than 10 m/sec.

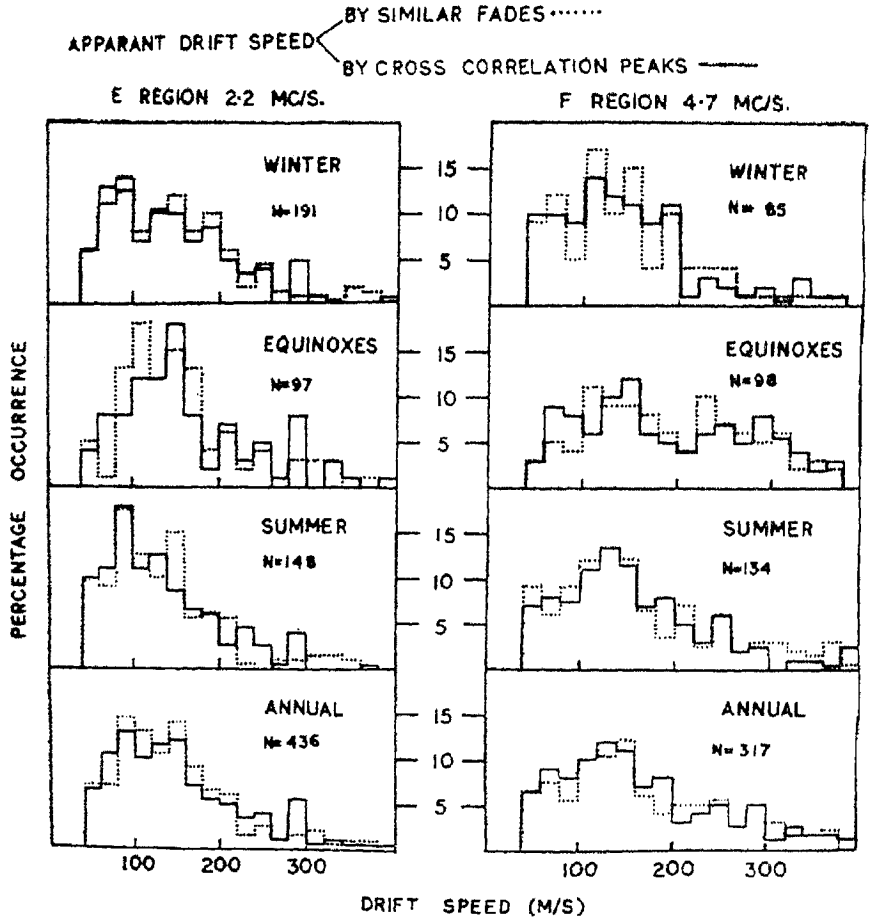

FIG. 4. Histograms of drift speeds for E and F regions according to the similar fades and optimum cross-correlation methods.

In Fig. 5 are shown the histograms of drift direction for different seasons by the two methods. The values determined by the similar fade method are slightly more concentrated in the Westward direction (270°). The mean value of drift direction was calculated using all the values between 240° and 300°. The difference between the mean values ($\bar{\theta}$) determined by the two methods range from 1° to 6° with an average difference of 4°. Statistical information regarding drift direction is given in Table III.

It may be mentioned that detailed analyses of drift records have shown that the irregularities causing the fading of radio waves over Thumba are greatly elongated along the north–south direction.

TABLE III

The median (θ^*), lower quartile (Q_1), upper quartile (Q_3), mean (θ) and standard deviation of the sample (σ_θ) and standard error ($\sigma_{\bar{\theta}}$) of the drift direction in the E and F regions of ionosphere over Thumba calculated by similar fades method (S) and by cross-correlation method (X) separately

	E-Region						F-Region					
	Winter		Equinox		Summer		Winter		Equinox		Summer	
	Method S	Method X	Method S	Method X	Method S	Method X	Method S	Method X	Method S	Method X	Method S	Method X
Median (θ^*)	270	270	270	270	270	267	270	270	270	270	270	269
Lower quartile (Q_1)	270	270	270	270	270	270	270	270	270	270	270	270
Upper quartile (Q_3)	270	278	270	270	270	270	270	275	270	277	270	274
Mean (θ)	269	273	268	274	268	271	269	270	268	272	268	271
Standard deviation of the sample (σ_θ)	8	11	6	8	7	8	4	5	6	11	7	8
Standard error of the mean ($\sigma_{\bar{\theta}}$)	0·6	0·8	0·6	0·8	0·6	0·6	0·4	0·5	0·6	1·1	0·6	0·7

All directions are in degrees North Eastern Clockwise direction.

CONCLUSION

The apparent speed and direction of the ionospheric drift by the simple similar fades method are not significantly altered by more detailed calculations of the time shift by optimum cross-correlation method between the records from pairs of antennae. The predominantly westward direction of drift at Thumba and large speeds may be taken as real.

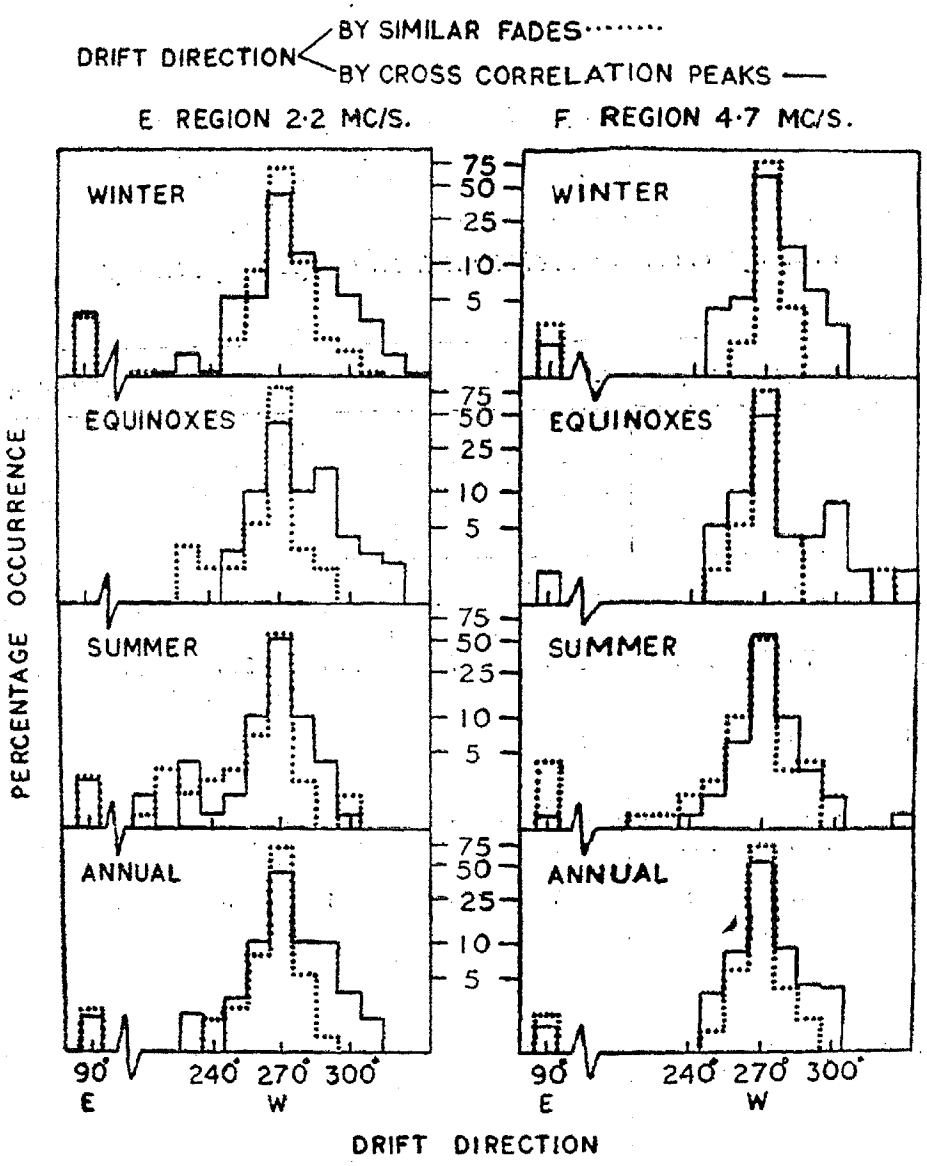

FIG. 5. Histograms of drift directions for E and F regions according to the similar fades and optimum cross-correlation methods.

ACKNOWLEDGEMENTS

Thanks are due to Prof. K. R. Ramanathan for the keen interest during the course of the work. One of us (M. R. Deshpande) was recipient of a scholarship from the Ministry of Education, Government of India.

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