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Long Term Variations of Ionospheric Horizontal Drift and Anisotropy of E-region Irregularities at Waltair

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Abstract

The study of long term variation of drift and anisotropy parameters of E region irregularities is particularly important because of the fact that D_1 method measures movements of ionization that corresponds with neutral air motion in this region and facilitates a comparison with other methods of measuring winds in this region. The study of horizontal movements of small scale ionospheric irregularities at Waltair (17.7^0 N; 83.3^0 E) using D_1 technique was started as early as I.G.Y.period. In this paper we present the results of observations of the drift and anisotropy parameters of ionospheric irregularities during equinox season over a span of about 10 years from 1957 to 1966 covering both the I.G.Y.and I.Q.S.Y.periods.About 140 midday (10-14 hrs) E-region drift records taken on frequency of 2.4 MHz are selected for the present study. There is an overall increase observed in the velocity parameters Va, V and Vc with the increase of sunspot number. The structure size, **a** of the irregularities shows a negative variation with sunspot number, decreasing magnitude with increase in sunspot number. There seem to be seasonal variation in the long term variation of some of the drift parameters with respect to solar epoch at Waltair.

Keywords: Close spaced receivers; Ground diffraction pattern; Ionospheric irregularities; Sunspot number.

1. Introduction

The author in [1] stressed the importance of the study of long term variation after noticing the change in the direction of the night time NS component of the F-region drift speed at Cambridge(52^0 N; 10^0 E) from sunspot minimum to sunspot maximum. The authors in [2] found a positive correlation between the F-region drift speed and sunspot activity.

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The authors in [3] found that from the drift measurements made in the LF range over a span of 12 years at Kuhlungsborn and Colln, the first indications for a probable solar cycle dependence of drift parameters in the lower ionosphere and later reported in 1969 a genuine effect of solar activity on the harmonic components of drift velocity. However, the author in [4] showed that no significant difference between the speeds of drift of irregularities over Rostov-on-the-Don (47.2^0 N; 39.7^0 E) over the solar cycle. The author in [5] found from the examination of drift data taken at Ahmedabad ((23.0^0 N; 72.6^0 E) over a span of 10 years that no significant difference between the speeds of drifts of irregularities and sunspot activity. In addition to, at Thumba (8.6^0 N;76.9^0 E), the author in [5] found that the apparent drift was reduced slightly while the true drift was reduced considerably with the increasing sunspot activity.

Review of literature

The author in [6] observed that at day time the drift speed variation during equinoxes was less distinct. The most probable direction of day time drifts was predominantly towards west. At Irkutsk ((52^0 N;104^0 E). The author in [7] found that the drift speeds and especially the meridional movement increases with the decrease of sunspot activity during the period 1958-1964 while the drift directions during the equinoxes were almost random. The author in [8] found that E-region drift velocities were independent of sunspot conditions at Ibadan (7.4^0 N;4.0^0 E). The authors in [9] from a study of the horizontal drift over Sibizmir(dip 72^0 N) during 1970-1975 reported that the drift speed decreases with sunspot activity during the equinoxes, while the drift directions was found to be mostly towards east. The author in [10] studied the variation of noontime E-region drift speed with the phase of sunspot cycle at Udaipur (24.6^0 N) and found that there is a reduction in drift speed with increase of sunspot number. Using almost 10 years of incoherent scatter radar EW drift measurements at Jicamarka (12.0^0 S;76.9^0 W), the authors in [11] found that the day time westward drift changes very little with solar cycle and the night time maximum eastward drifts tend to be high during sunspot maxima compared to sunspot minima. Using one solar cycle data at Udaipur during the period 1971-1983, the authors in [12] studied the variation of day time E and F region drift speeds with solar activity and found that the drift speed decreases with the increase of solar activity. At Waltair (17.7^0 N;83.3^0 E), the authors in [13, 14] studied the influence of sunspot activity on horizontal drift and anisotropy parameters of E-region irregularities during winter and summer seasons respectively. The average values of the length of the semi-major axis 'a' and the difference angle ($\varnothing$-$\varnothing_a$) showed a positive variation with sunspot activity decreasing in magnitude with decrease in sunspot activity, both during winter and summer seasons. However, while no systematic or significant variation was found in the average values of the true drift speed during summer, the author in [13] found a marked decrease during winter with the decrease of sunspot activity. The author in [13] noticed that the average values of V_C and **r** to be higher during high sunspot years corresponding to winter season. However, the summer values of V_c and **r** did not show any such variation with sunspot activity. At Udaipur (Geomag.lat 14.5 N), low latitude station, the authors in[15] measured the daytime E-region drifts for the high solar activity periods(1978-1980) and low solar activity periods(1973-1975) during equinoxes(March, April & September, October months).They studied different parameters of ionospheric irregularities and reported that the median value of the apparent drift speed during equinoctial months is 53 m/s for the high sunspot periods whereas for the low sunspot periods the apparent drift values occur in the range 20-60 m/s with the median value 56 m/s.The ratio Vc/V lies 0.4 –0.6 for high sunspot periods and 0.2-0.8 for low sunspot periods. The axial ratio **r** lies between 1-2.5 for high sunspot periods and almost 77% lies for the low sunspot periods.

Statement of the problem

The foregoing review brings forth clearly the importance of the study of solar activity dependence of drift and anisotropy parameters of the ionospheric irregularities.Also,it can be seen from the above studies that there seems to be some seasonal variation in the dependence of drift parameters, particularly the true drift speed, on solar activity being unaffected during summer, but found to decrease with the decrease of sunspot activity during winter.However,no attempt has so far been made at Waltair to study the long term variation of drift parameters during equinox season. The importance of the study of the long term variation and the lack of complete information even though the data was available at Waltair, has prompted the authors to study the long term variation of the drift and anisotropy parameters of E-region irregularities during equinoctial months. It is also felt that such a study would enable the authors to make an assessment of the seasonal dependendence of the long term variation of the above parameters at Waltair. The data used for this study and the method of analysis are described in the following section.

Limitations of the study

The changes in the upper atmosphere have been found to be closely related with the variation in solar activity and geomagnetic variation. In addition to, the long term variations in the neutral temperature of the upper atmosphere were correlated to the variation in the solar electromagnetic radiation, whereas short term fluctuations were strongly related with changes in geomagnetic activity. We have undertaken a comparative study of the results of the present investigation dealing with the effect of the sunspot activity on the drift and anisotropy parameters of irregularities in the E-region, with those observed at other stations and by other investigators .As our study is predominantly confined to the equinox season, it is to be mentioned that very meager information of a direct nature is available in the existing literature on drift studies, dealing with this aspect of study. Hence a comparison of the reported results from each of the different stations corresponding to different epochs of the solar cycle is also made to deduce any trends of the effect of sunspot activity on the drift parameters. But even this procedure is found to be handicapped in two respects.Firstly,the results reported from a station for periods of differing sunspot activity do not always correspond to those obtained by a unique method of analysis and secondly, the frequency used to probe the ionospheric region is not the same throughout.However,inspite of all these inadequacies an attempt is made as mentioned above to compare the results of the present study with those at other stations revealed from the reported results for any possible evidence of the dependence of the parameters of drift and anisotropy of irregularities taking into account such important factors as the differences in the method of analysis etc.

2. Data and method of analysis

The present study is made using data obtained at Waltair during equinox season over a span of about 10 years from 1957 to 1966 covering both the I.G.Y. and I.Q.S.Y.periods.About 140 midday (10-14 hrs) E-region drift records taken on frequency of 2.4 MHz belonging to equinox season (comprising March, April&September,

October months) during the period 1957-1966 are selected and were treated by the correlation function method due to the authors in [16, 17].In presenting the results, greater emphasis is placed on the variation of the drift parameters with sunspot activity and for that the values of various parameters are plotted against the sunspot number, Rz.All the velocities reported in this study correspond to the velocities of the irregularities of ionization at the point of reflection (half the velocity of ground diffraction pattern)

3. Results

3.1 Drift parameters

3.1.1 Apparent drift velocity, Va

The velocity has retained its importance in the study of drift of small scale irregularities since it is related to the true velocity through the anisotropy of the ground diffraction pattern and since it is supposed to be equivalent to the velocity obtained by Mitra's similar fades method which has been extensively applied due to its simplicity.Fig.1.represents the scatter plots of the midday value of the apparent drift speed with Zurich sunspot number. Regression line was drawn through data points representing values of drift versus sunspot number; Rz.The curve shows a slight increasing trend in the magnitude of the Va with increase in sunspot number.

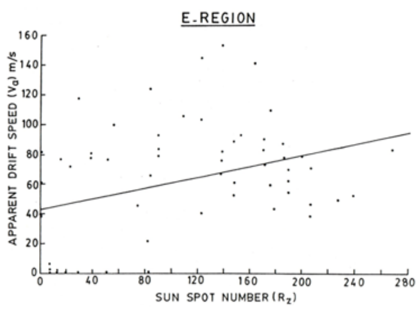

Figure 1: Variation of apparent drift velocity [Va] with sunspot number [R_z]

3.1.2 True drift velocity, V

The curve depicting the variation of the true drift velocity of the E-region irregularities with the sunspot number in the form of a scatter plot is presented in Fig.2.It is evident from the Fig.2 that the least square line shows increasing trend in V with the increase of R_z..

3.1.3 Random velocity, Vc

The variation of the value of Vc, a measure of the random changes taking place in the signal patterns, with the sunspot number is presented in Fig.3.This figure shows that there is an increasing trend between the random velocity,Vc and the sunspot number,Rz.In Fig.4 is depicted the scatter plot of the "Inverse turbulence ratio" Vc/V which gives the importance of the random changes compared to the steady drift versus the sunspot number, Rz.The figure shows no variation in the rationVc/V with the increase of the sunspot number. From what has been reported above it is evident that random movements within the structure of the irregularities play an equally important role in producing the fading observed at this station and the relative importance of random movement to bodily drift shows no variation with increase in sunspot number.

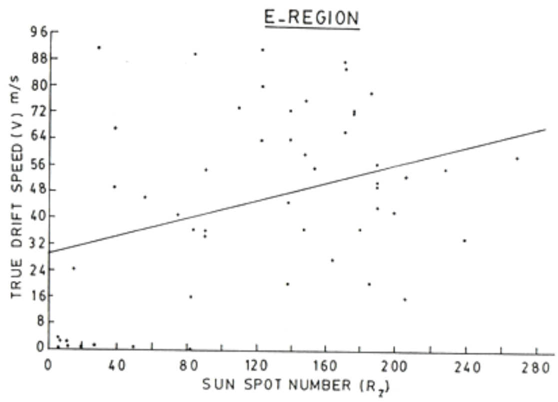

Figure 2: Variation of true drift velocity [v] with sunspot number [R_z]

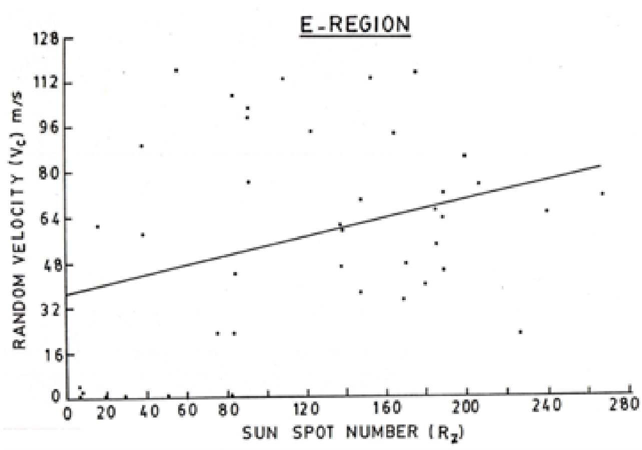

Figure 3: Variation of ratio of random velocity [Vc] with sunspot number [R_z]

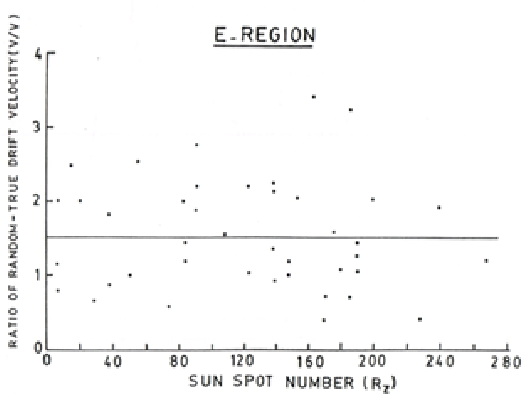

Figure 4: Variation of ratio of random – true drift velocity [Vc/V] with sunspot number [R_z]

3.1.4 The difference angle, (∅-∅ₐ)

This angle gives the difference between the true and apparent drift directions and hence serves as a discrepancy factor between the apparent and true drift speeds. From the Fig.5 it is noticed that the magnitude of **($\emptyset$-$\emptyset_a$)** ,the difference between true and apparent drift directions decreases with increase of sunspot number and the difference is found to be reduced by a factor of 2 in the range of sunspot number activity considered. As this difference angle depends on the shape of the pattern as well as on the orientation of the pattern with respect to the drift direction, it can be stated that the observed variation of **($\emptyset$-$\emptyset_a$)** can be viewed as indicating those shapes and orientation of the pattern which give rise to less deviation of the apparent direction from the true drift direction during epochs of higher sunspot activity.

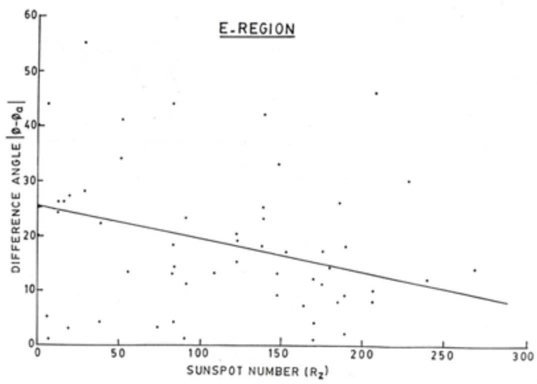

Figure 5: Variation of difference angle [$\emptyset$-$\emptyset_a$] with sunspot number [R_z]

3.2 Properties of the ground diffraction pattern

3.2.1 Axial ratio, r

The variation of the value of the axial ratio **r** of the characteristic ellipse with the sunspot number, Rz is shown in Fig.6 .From the figure, it is clear that the axial ratio **r** decreases with the increase of sunspot number. From the general decrease of the axial ratio observed from the minimum sunspot number to the maximum sunspot number, it can be stated that the anisotropy has a tendency to decrease with the increase of sunspot number.

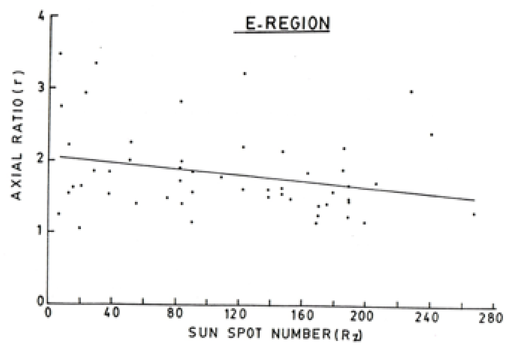

Figure 6: Variation of axial ratio[r] with sunspot number [R_z]

3.2.2 Orientation of the semi - major axis,ψ (^{0} N of E)

Though in the actual method of analysis the orientation of the minor axis ψ ^{0} N of E of the characteristic ellipse is evaluated, it is usually convenient to present the orientation of the major axis in degrees N of E, in order to have an idea about the extent to which the major axis deviates from N-S or the magnetic field direction along which it is supposed to align itself at the low latitudes. The scatter plot showing the variation of the value of the orientation of the semi-major axis with the sunspot number, Rz is presented in Fig.7.The irregularities show a tendency for westward orientation with decrease in sunspot number. From the Fig.7 it is understandable that the alignment of the major axis is more westward during the period of minimum sunspot activity compared to the maximum activity period, indicating that the electron density gradients are less along the N-S direction during the period of maximum sunspot activity.

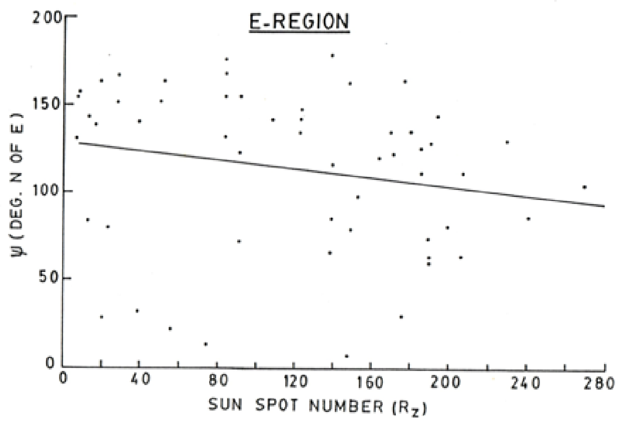

Figure 7: Variation of orientation of semi-major axis[ψ] with sunspot number [R_z]

3.2.3 Size of the irregularity, a

In the present investigation the scatter plot showing the variation of the size of the irregularity, given by the length of the semi-major axis of the characteristic ellipse (ρ = 0.61), with the sunspot number is presented in Fig.8**.**Considering the overall behavior of the size, it can be said that the size has increased with the decrease of sunspot number. It is therefore concluded that the structure size of the irregularities in the E-region shows a negative variation with sunspot number, decreasing in magnitude with increase in sunspot number.

3.3 Comparison of the results with earlier work and discussion

A detailed comparison of the results of the present study with those of other investigators is now presented. The author in [1] noticed that the night time NS component of F-region drift at Cambridge changed direction from south during sunspot maximum to north during sunspot minimum, a result which made him to stress the importance of a detailed study of the long term variations in the drift and anisotropy parameters. The author in [18] made observations on 3.2 MHz for the E-region and reported the quarterly average values of the drift and anisotropy parameters at Puerto Rico.He adopted the modified method of the author in [19] wherein he assumed a triangular approximation to the correlation function, in the evaluation of the parameters of drift and anisotropy.

He reported the yearly average value of the drift speed to be 83 m/sec(except the third quarter).

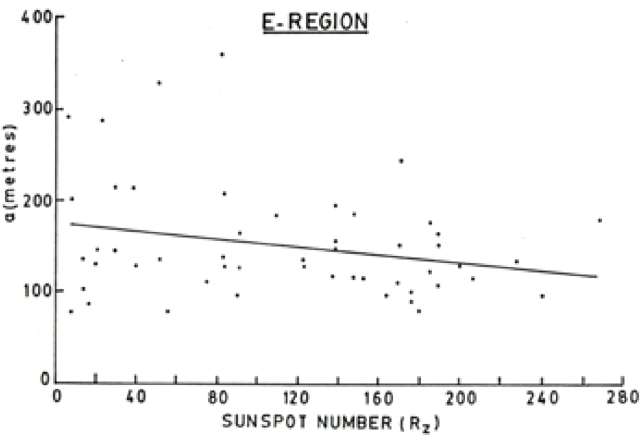

Figure 8: Variation of structure size [a] with sunspot number [R_z]

However, the author in [19] worked at the same place on a frequency of 2.33 MHz during winter months of 1954 and during June 1954 – a year of low solar activity and reported a value of drift speed which was equal to 28 m/sec.The marked difference in the average values for the two periods is believed to be mostly due to the method of analysis adopted since the comparative study of the different methods of analysis by the author in [20] revealed that the method adopted by the author in [19] exaggerates the effect of random motions, and gives very low values for the true drift speed. Thus the results available from Puerto-Rico during the different epochs of the solar cycle make it difficult to draw any definite conclusion regarding the dependence of drift speed on solar activity. Now, the results of the drift obtained from the study of the low frequency experiments at different epochs of the sunspot activity at different stations obtained during equinox seasons will be considered examining the published work from University Park(40^0 47^1 N;77^0 56^1 W) Pennsylvania where we have the results of Sales and Bowhill who gave a value of 22 m/sec for the true drift velocity from the observations made during October 1958 on a frequency of 60 KHz corresponding to the height of the D-region. This value is smaller compared to the value of 40 m/sec and 90 m/sec for the periods July 1951 and March 1952 respectively given by the author in [21] who used the method of the author in [22] for the observations on a frequency of 150 KHz and which correspond to a height range 83-100 km.The value of 33 m/sec given by the author in [23] for the year 1961,from the observations on 300 KHz which refer to a height range of 95-100 km is also larger compared to the values reported by other investigators. Although these observations refer to different periods of solar activity, no conclusion can be drawn regarding the variation as they refer to different operating frequencies and hence different levels at the bottom of the E-region. Sufficient information of height gradients is not available so as to reduce them relevant to a common height and compare drifts for different periods. However, the investigations made at Cambridge during the periods of differing solar activity show a tendency of a positive variation of the drift speed and the size of the irregularities with solar activity.Cilliers(1960) working on 113 KHz has got the drift velocity equal to 35 m/sec during the period March-June 1958.A comparison of the above value with the value of 20 m/sec obtained by the author in [24] for the period April-June 1952 on 71 KHz reveals a pronounced decrease of drift speed with decrease of solar activity. However, it is to be noted that the difference in the values cannot be taken to be totally due to the change in solar activity as the probing frequencies are different and hence correspond to different heights. From the results of ionospheric drift measurements in the low frequency range over a period of about 10 years,Sprenger and Schminder(1967) obtained the first indications for a probable solar cycle dependence of drift parameters in the lower ionosphere.Later,the investigations of the author in[5] from a study of the effect of solar activity on the drift parameters of irregularities in E-region at Ahmedabad, showed no significant variation in the magnitude of the drift speed with solar activity, which is at variance with the findings of the present investigation. The author in [4] made a detailed comparative study of the E-region drifts obtained over Rostov-on- the Don (Lat:47.2^0 N;Long:39.7^{0}E) during the periods of maximum solar activity i.e., I.G.Y.and I.Q.S.Y.and noticed no significant change in the drift speed for the two epochs. At Waltair, during winter season, the author in [13] observed a decrease in the true drift velocity of E region with the decrease of sunspot activity, whereas the apparent drift velocity has shown no marked change. Also at Waltair,the author in [14] observed no systematic variation in the drift velocity(Va,V) with the decrease of solar activity during summer season y.The authors in [8] found at Ibadan that the drift velocities are independent of the sunspot number,R_z ,during the period from 1957-1974 during equinoxes. The author in [10] studied the variation of the E- region drift speed in equinoxes during the periods 1971-1975 and 1979-1981 and showed that the drift speed decreases with decrease in sunspot number. The authors in [12] obtained the day time drift speeds at Udaipur, a low latitude station for different periods since 1971 up to the year 1983 and reported that the day time true drift speed of E region decreases with the enhancement of the level of solar activity. The present study reveals that there is a tendency for the drift to increase with the increase of sunspot number. Thus, the present result is in agreement with the findings of the authors in [10, 13], but in disagreement with the findings of the authors in [5, 12]. As per the observations of the random velocity, at Thumba, during the period 1964-1969, the author in [25] showed that there is no systematic variation of the quantity Vc/V with increasing sunspot number. At Udaipur, the authors in [12] observed an increase in the ratio Vc/V with the enhancement of intensity of solar flux during equinoxes. The author in [13] found that no systematic variation of Vc/V with the sunspot activity during winter season at Waltair. The author in [14] found that no systematic variation of the ratio Vc/V with sunspot activity at Waltair during summer season. The present study reveals no variation in the ratio Vc/V with increasing sunspot number which is in conformity with the findings of the authors reported in [25,13.14], but contrary to the findings of the authors reported in [12] who noticed positive correlation between the ratio Vc/V and sunspot number during equinoxes. In the present investigation, the axial ratio **r** is found to decrease with the increase of sunspot number. Similar variation has been observed by the authors in [12] who found that the day time mean value for the axial ratio **r** during equinoxes as 1.98 for the maximum sunspot activity period and 2.5 for the minimum sunspot activity period. At Waltair, the author in [13] observed that a general decrease in the axial ratio with the decrease of the sunspot activity, the author in [14] reported that it was independent of solar activity during summer season. The results of the present study are different from the findings of authors reported in [12, 14]. The published work dealing with the spatial properties of the ground diffraction pattern at different stations during periods of differing solar activity in the case of E region will now be considered to bring into light any changes that have occurred in the various parameters owing to changes in solar activity and a comparison will be made of the solar activity dependent features observed by other investigators with those of the present study. The author in [14] studied the variation of orientation of the major axis of the characteristic ellipse ψ ,over a half solar cycle at this station and concluded that the orientation of the major axis is dependent to a significant degree on the epoch of the solar cycle. The author in [12] also arrived at the same conclusion at Udaipur. The present investigation reveals that the major axis of the ellipse changes its orientation gradually towards west from sunspot activity maximum to minimum which is in conformity with the findings of the author in [13] at this station. The authors in [13, 14] found that an overall decrease in the length of the semi-major axis with decrease of sunspot activity at Waltair (pertaining to winter and summer seasons respectively).The result of the present study pertaining to equinox season shows that an increase in the size with decrease of solar activity, is at variance with the findings of the authors in [13, 14]. From the foregoing comparison of the results reported at Waltair and other places, it could be inferred that there seems to be some seasonal variation in the variation of drift and anisotropy parameters with solar epoch. To bring out the differences clearly, the results of the studies on the long term variation made by the authors in [13, 14] at Waltair are reproduced in the Fig.9. along with the results of present study. The observations are also summarized in Table 1.

Table 1: Earlier results of the investigations reported at Waltair for winter and summer seasons

Season	**V**	**V_a**	**V_c**	**a**	**r**	**ψ**	**($\varnothing$-$\varnothing_a$)**
Equinox (present study)	decreases with decrease of sunspot activity	decreases with decrease of sunspot activity	decreases with decrease of sunspot activity	decreases with increase of sunspot activity	decreases with increase of sunspot activity	decreases with increase of sunspot activity	decreases with increase of sunspot activity
Winter Jogulu (1968)	decreases with decrease of sunspot activity	No variation	No variation	decreases with decrease of sunspot activity	decreases with decrease of sunspot activity	decreases with decrease of sunspot activity	decreases with decrease of sunspot activity
Summer Sastri (1970)	No variation	No variation	No variation	decreases	No variation	No variation	decreases

From the Table 1, it can be seen that the drift and anisotropy parameters show a definite seasonal dependence, particularly, during equinoxes at Waltair.Similar seasonal variation in drift speeds and directions have been noticed by earlier workers during IGY and IQSY (Poljakov and his colleagues 1968; Kazimirovsky and Kokorov, 1972).Also, the observed variation in the drift parameters during equinoxes may be associated with a reversal of the atmospheric circulation.

The present study covering all seasons, thus, provides a complete picture of long term variation of drift and anisotropy parameters of E – region small scale irregularities at Waltair.

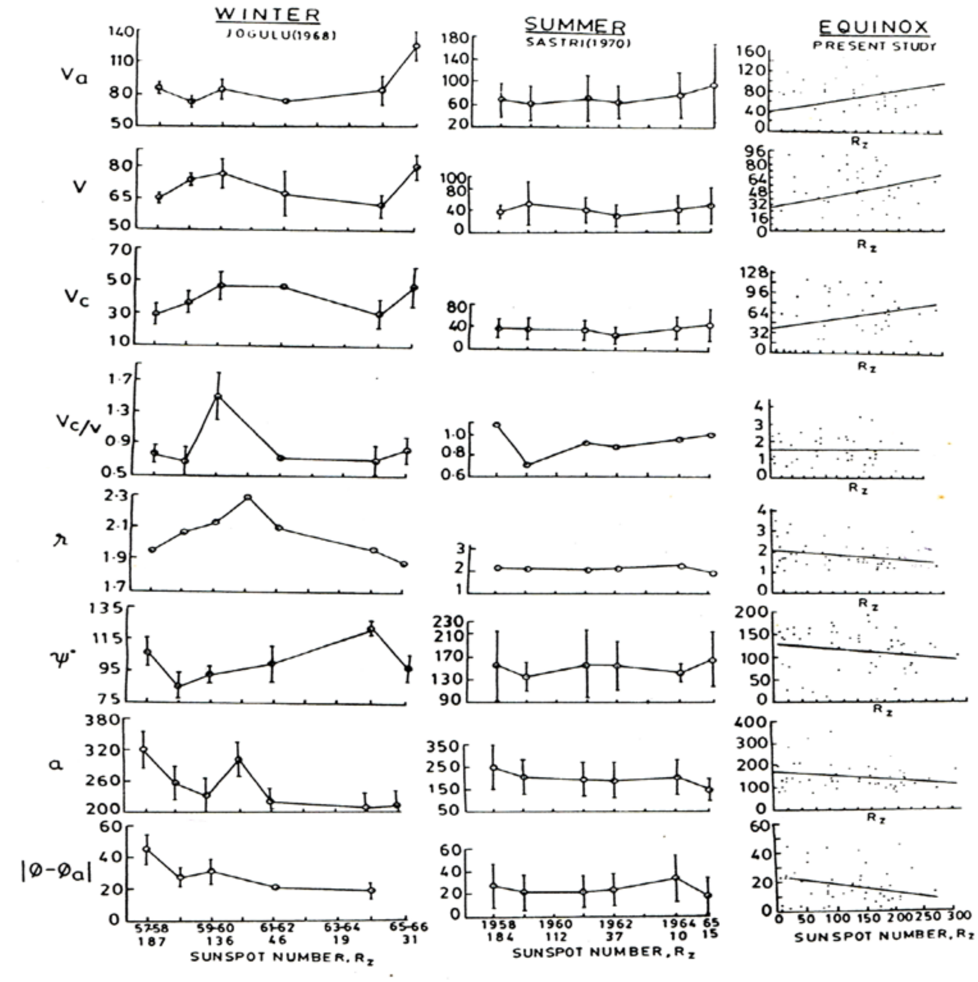

Figure 9: Long term **V**ariation of drift and anisotropy parameters with solar epoch

4. Conclusion

The following are the major conclusions arrived at from a study of the drift and anisotropy parameters of irregularities in the E – region at Waltair, during equinoxes over a period of about 10 years during 1957 to 1966. There is an overall increase observed in the velocity parameters Va, V and Vc with the increase of sunspot number. There is no systematic variation in the ratio Vc/V with sunspot number. The structure size, **a** of the irregularities shows a negative variation with sunspot number, decreasing magnitude with increase in sunspot number. The axial ratio **r** is found to decrease with increase of sunspot number. The orientation of the major axis of the characteristic ellipse is preferentially westward during low sunspot activity years ($R_z < 20$) than during high sunspot activity years (($R_z > 250$).There seem to be seasonal variation in the long term variation of some of the drift parameters with respect to solar epoch at Waltair.

5. Recommendation

An understanding of the long term variations of the ionospheric irregularities in the E-region during different seasons at different latitudes requires predominantly the study of the observations for the distribution of energy in the upper atmosphere due to the solar activity and how different regions of terrestrial atmospheres are coupled together. For this, a more coordinated approach by taking simultaneous observations of ionospheric irregularities at various stations located at different latitudes and longitudes and during different seasons with specific sunspot activity periods are required. It is proposed to undertake such a study in the near future.

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