The Effect of Geomagnetic Storm in the Ionosphere using N-h Profiles.

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ABSTRACT

This study presents the ionosphere effects of geomagnetic storms using N-h profiles. The data used are from ionograms at Ibadan (Latitude 7^0 26^0N, longitude 3.54^0 E and magnetic Dip of 6^0S. the result show a lot of variations as there are positive and negative storm phases. The disturbance daily variation of the electron density NmF_2, the height of maximum electron density NmF_2 and the sub peak electron density n_T were then obtained to study the correlation between the disturbed and quiet days.

(Keywords: ionosphere effects, geomagnetic storms, ionograms, electron density)

INTRODUCTION

The ionosphere is greatly affected by solar disturbance such as appearance of sunspots, solar flares and corpuscular streams which are accompanied by an increase in velocity and concentration of the solar wind thus ejecting more energetic ions which are observed on the earth's surface as geomagnetic storms.

Geomagnetic storms are usually associated with increased electron densities in the lower ionosphere (30 – 500 km) and simultaneous increase in absorption of radio waves.

Magnetic storms usually last 24 to 48 hours, but some may last for several days. The severity of geomagnetic storms is usually explained with the help of Dst (disturbance storm time) index as well as K_p index (weighted average of k-indices from a network of geomagnetic observation i.e. planetary K indices).

There are many theories of magnetic storm as far back as 1930 in which it was discovered that the polar ionosphere was distributed during geomagnetic storms.

Polar blackout phenomenon and auroral E echoes were noted which are abnormal ionization at lower heights due to incoming energetic particles. Sudden ionospheric disturbance in an ionospheric radio fade out followed by bright solar flare is also associated with geomagnetic storm.

E region disturbance is due to enhanced ionization produced by burst of solar radiation or precipitation of energetic charged particles the ionosphere while F region shows decrease of electron density generally due to vertical drift motion of electrons. D region disturbance is due to an excess ultra-violet radiation producing increased ionization causing strong absorption of radio waves passing through.

The disturbance effect in the F_2 layer is remarkable during a geomagnetic storm. It has been found that in high latitude, a marked depression of the peak of maximum electron density of the F_2 layer NmF_2 or F_0F_2, the critical frequency of the F_2 layer occur; in the low latitude, an increase of electron is very common notable only in very severe storm, and in the middle latitude there is a depression except for an occasional increase during winter and a marked diurnal control.

Many geomagneticians in their past works using N-h profile analysis confirmed above statement and also found that the total number of electrons below F_2 peak referred to as the sub peak electron content behaves the same way. Also electron above 200km changes as mentioned above and it increases at the equatorial stations during geomagnetic storms, i.e., there is an increase and decrease in electron content during geomagnetic storm in the F- region, thus there is no re-distribution of electron in that layer.

The effect of storm in the F – region has been attributed to the electromagnetic drift theory caused by movements of ions from below the F – region by strong and highly conducting field lines.

Past studies on storms used parameters such as F_0F_2 or NmF_2 and minimum virtual height h' or hm which are rather unreliable, particularly during storm in deducing height changes, because it contains considerable group retardation effect due to lower ionosphere regions.

This present paper examines the effect of geomagnetic storm using the N-h profile in which several storm events whereby a storm event is 2 quiet days preceding and a day after a disturbed day such that a good study of the transition from the quiet day to the disturbed day was done.

DATA AND METHOD OF ANALYSIS

Ionosonde data obtained from the station of the University of Ibadan, Ibadan in Oyo state, Nigeria (Geo. Lat. 7^0 26^0N, Long. 3.54^0 E, Dip. 6.5^0) for the geomagnetic storms chosen from July 1957 to December 1958, which is a year of sunspot maximum have been utilized in this study. Eight storms were chosen which had two preceding quiet days to study the transition from the quiet days to the disturbed day.

C_p between 0 - 0.6 was taken to be magnetically quiet days and C_p greater that 1.0 was taken to be magnetically disturbed day. Table 1 shows the value of C_p and A_p indices of the storm events analyzed.

Table 1: C_p and A_p Indices of the Storm Events.

Date	A_p	C_p
5/6/58	8	0.4
6/6/58	15	0.9
7/6/58	17	1.8
8/6/58	13	0.8
6/7/58	6	0.3
7/7/58	17	0.9
8/7/58	200	2.1
9/7/58	75	1.8
15/8/58	9	0.5
16/8/58	12	0.7
17/8/58	82	1.8
18/8/58	20	1.0
23/9/58	5	0.2
24/9/58	6	0.3
25/9/58	82	1.8
26/9/58	25	1.2

C_p= Geomagnetic planetary indices
A_p = Geomagnetic amplitude

The ionograms were reduced using single polynomial of 10 – point Kelso analysis for every hour during the period of both quiet and disturbed days to obtain true height h. the height of maximum density hm and N was deduced from:

$$f = \frac{1}{2\pi}\sqrt{\frac{Ne^2}{m\varepsilon_0}} \qquad \text{———} \qquad (1)$$

$$N = \frac{4\pi^2 m\varepsilon_0 f^2}{e^2} \qquad \text{———} \qquad (2)$$

$= 1.24 \times 10^4 f^2/cm^3$

The storm time profile were then plotted over the quiet time profile for each local time to obtain the induced effect. The storm affected N-h profile is as shown below

Correction for sunspot effect on quiet days sunspot number has a strong magnetic field therefore having some influence on the ionosphere, thus correction for the quiet day values of the sunspot is necessary. Using the data for short time variation. Zurich relative sunspot number Rz and the daily solar flux months of June to September 1985, the corrections are given by:

$$(N_mF_2)_R = (N_mF_2)_0(1 + 0.02\ R_z) \qquad \textbf{(3)}$$

and S = 50 + 0.967 R **(4)**

Substituting (4) into (3) gives:

$$(N_mF_2)_R = (N_mF_2)_0\left[1 + 0.02\left(\frac{S-50}{0.967}\right)\right] \qquad \textbf{(5)}$$

The corresponding $(N_mF_2)_R$ for each storm event is as shown in R Table 2.

Table 2: $(N_mF_2)_R$ for Each Storm Event

Date	$(N_mF_2)_R$
5/6/58	5.26
6/6/58	5.34
7/6/58	4.90
8/6/58	4.78
6/7/58	7.64
7/7/58	4.87
8/7/58	4.76
9/7/58	4.47
15/8/58	4.74
16/8/58	4.41
17/8/58	4.33
18/8/58	4.47
23/9/58	4.64
24/9/58	4.62
25/9/58	4.56

ERROR ESTIMATION

f_oF_2 change significantly not only with sunspot number, but also with photospheric faculae as shown by the relation for noon value.

f_oF_2= A + 0.028R + 0.0000672Ap where Ap is the area of ca-plages which has chromospheric feature of faculae and A is a constant which varies with respect to magnetic dip.

For Ibadan, A was found to be 6.77MH$_z$. in order to determine the range of possible error for the quiet day values and disturbed day, the error was calculated for the 12th hour of the quiet and disturbed days.

Using
Standard Deviation,

$$S.D = \sqrt{\frac{\sum(\triangle x)^2}{N}}$$

And the corresponding percentage standard error given by:

$$S.E = \frac{S.D}{\sqrt{N}} \times 100\%$$

Results obtained for each storm event is as shown in Table 3.

Table 3: Results for Each Storm Event.

Date	f_oF_2	% standard error
5/6/58	14.05	
6/6/58	13.52	2.7
7/6/58	12.37	
8/6/58	14.19	
6/7/58	15.04	
7/7/58	15.06	
8/7/58	14.62	1.6
9/7/58	14.38	
15/8/58	13.91	
16/8/58	13.54	
17/8/58	12.74	3.8
18/8/58	12.84	
23/9/58	13.49	
24/9/58	13.46	
25/9/58	12.58	2.5
26/9/58	13.32	

RESULTS AND DISCUSSION

The graphs of the analysis are as shown below Also the NmF_2,hmF_2 and n_T hourly variation with local mean time for each storm event are represented.

Disturbance Daily Variation

In June, NmF_2 is depressed slightly before noon, it then increased afternoon to decrease again at sunset hmF_2 decreased at sunset returning to normal afternoon, only to decrease at sunset.

The subpeak electron content behaved the same way as the ionization density, being depressed during forenoon and rises up again in the afternoon.

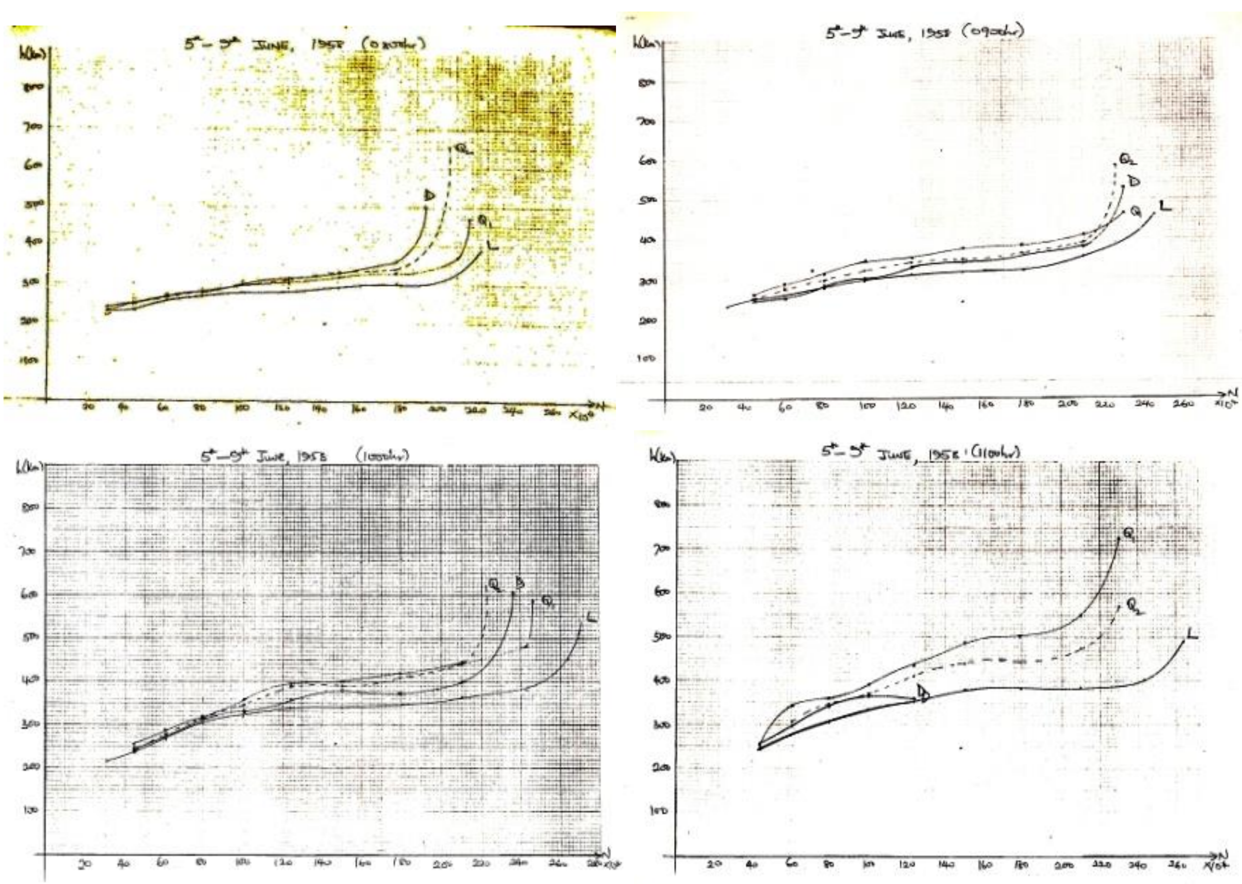
The month of July and September not discussed. In August, NmF_2 and hmF_2 behaved in a similar way to that of July. The sub peak electron content fluctuated in the early house of the day only to increase at sunrise with maximum at 1700 hours as shown.

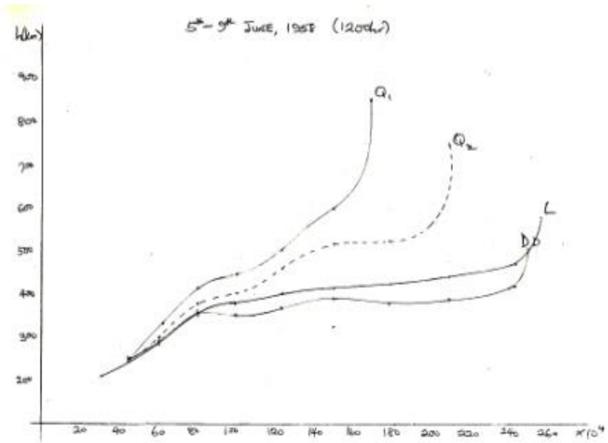
Diurnal Variation

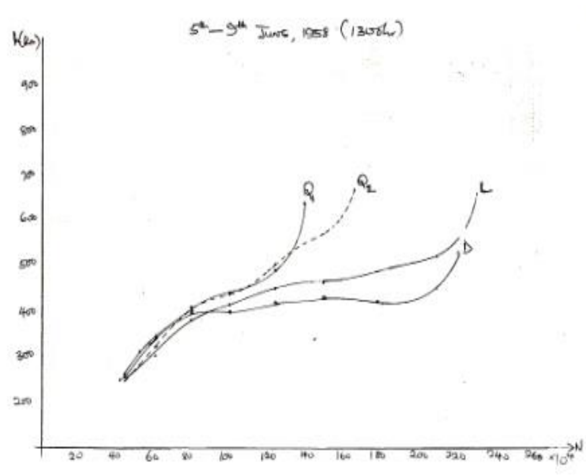
The hourly variation of Nmf_2, hmf_2 and the sub peak electron content n_T were also studied. In June, there is an increase in Nmf_2 with maximum at noon of the first day. It decreased till the early hours of the second day. The same trend was observed for the rest of three days as shown. The months of July and September not again discussed.

SUMMARY AND OBSERVATION

From the result of the N – h profile in July at 1200 hours, for the same NmF_2, there was an increase of about 25% in hmF_2 during the storm which was almost general for the storms observed, i.e., an increase or decrease of about +/- 25% likewise NmF_2 was reduced or increased by about 10 – 15% during the storms and generally from the results of the disturbance daily variations, it was observed that there is an inverse correlation between the variation in NmF_2 and height.




5th – 9th June, 1958 (1200hr)
h(km)
Q1
Q2
L
D
N ×10⁴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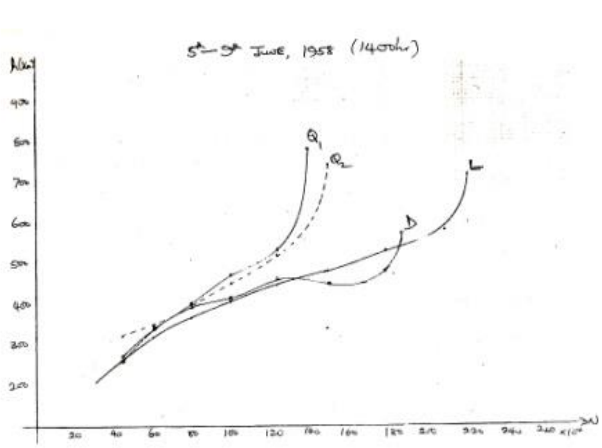
h(km)
Q1
Q2
L
D
N ×10⁴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h(km)
Q1
Q2
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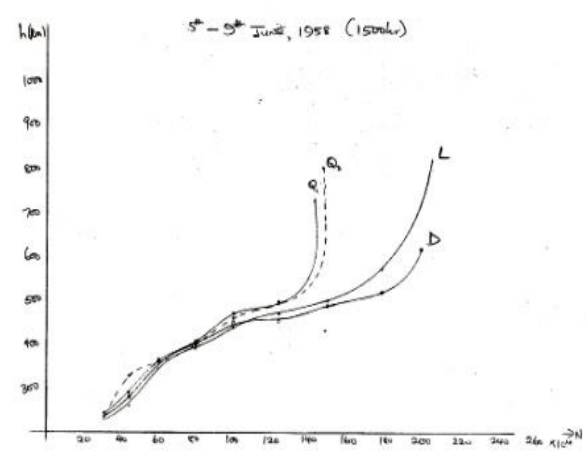
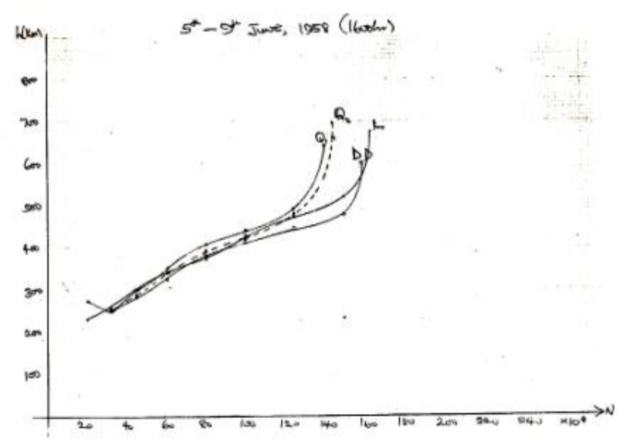
N ×10⁴


5th – 9th June, 1958 (1500hr)
h(km)
Q1
Q2
L
D
N ×10⁴


5th – 9th June, 1958 (1600hr)
h(km)
Q1
Q2
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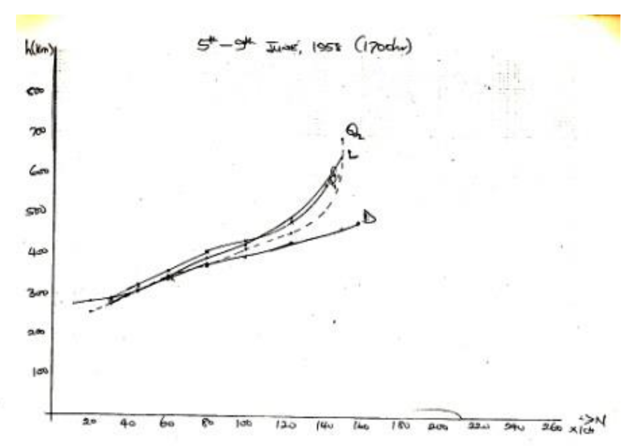
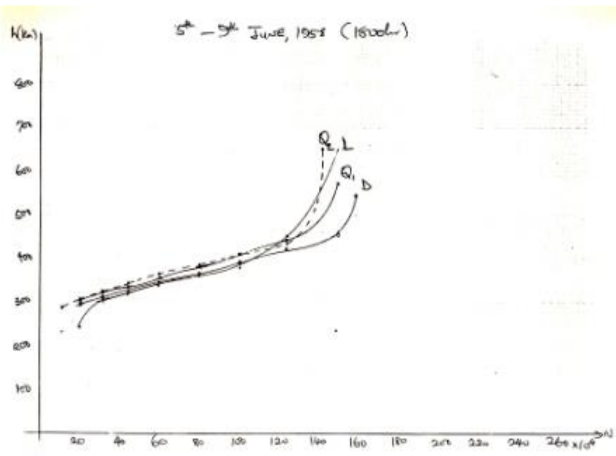
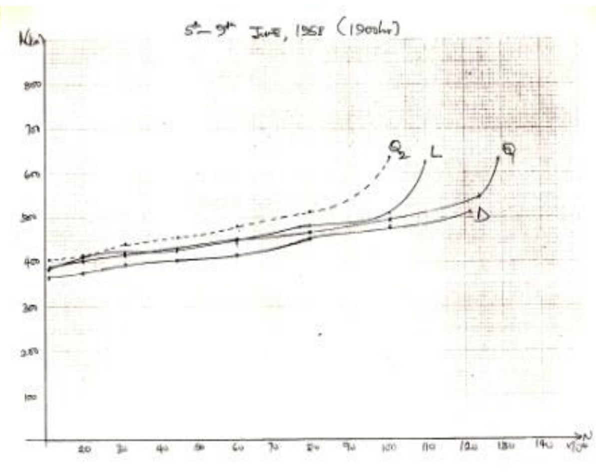
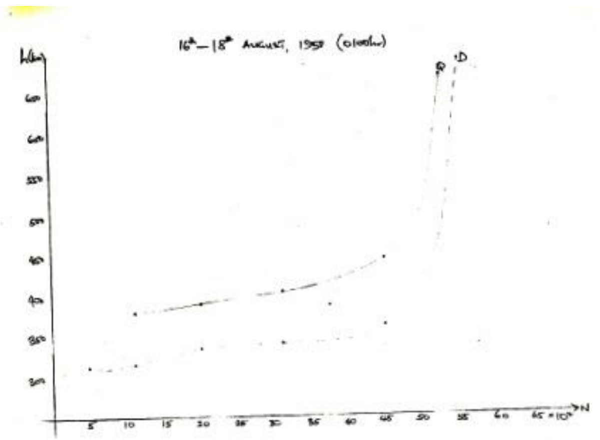
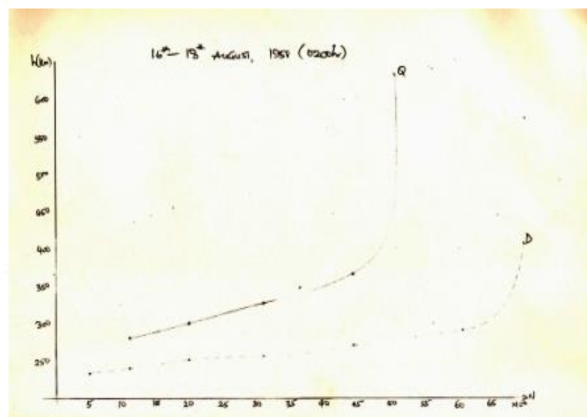
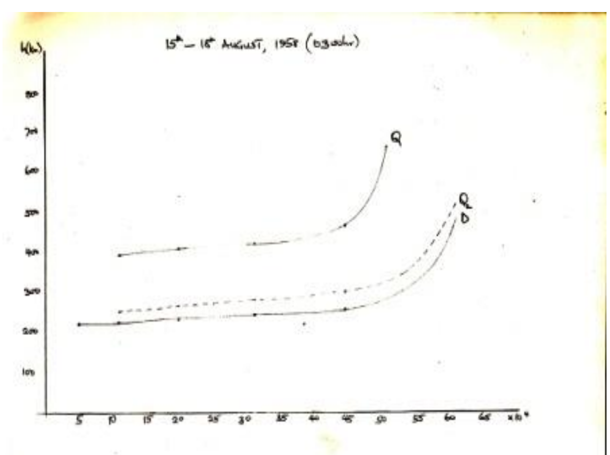

5th – 9th June, 1958 (1700hr)
h(km)
Q2
L
D
N ×10⁴

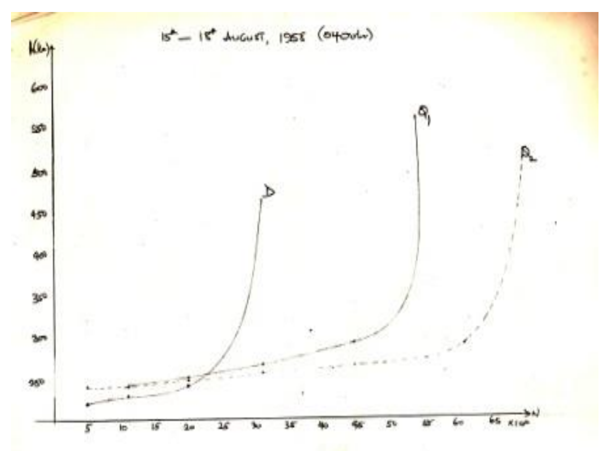


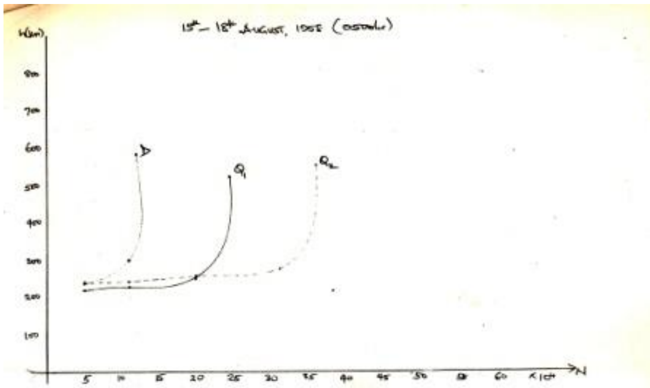


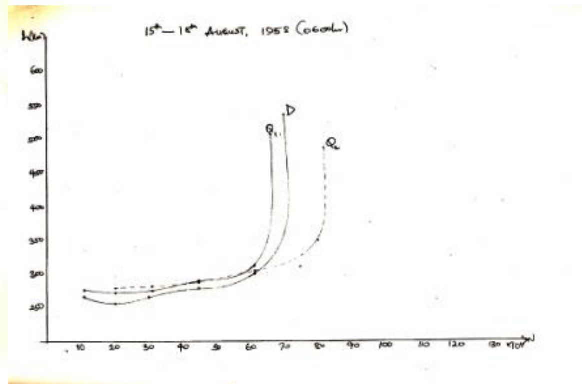


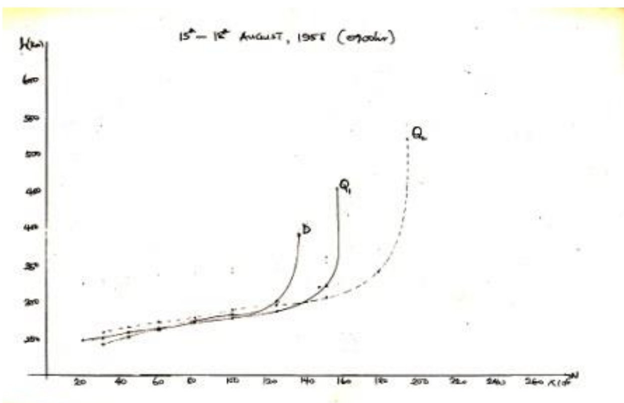


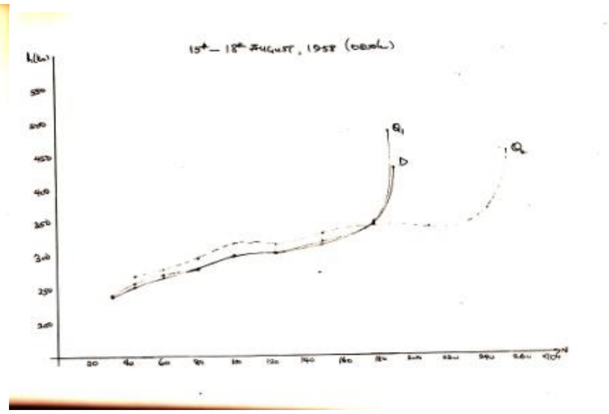


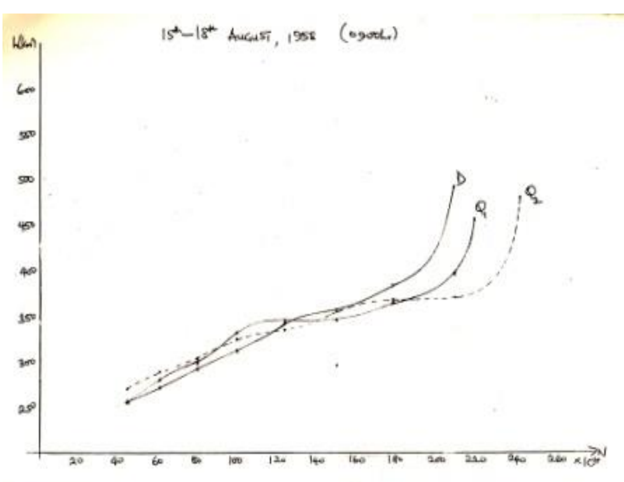


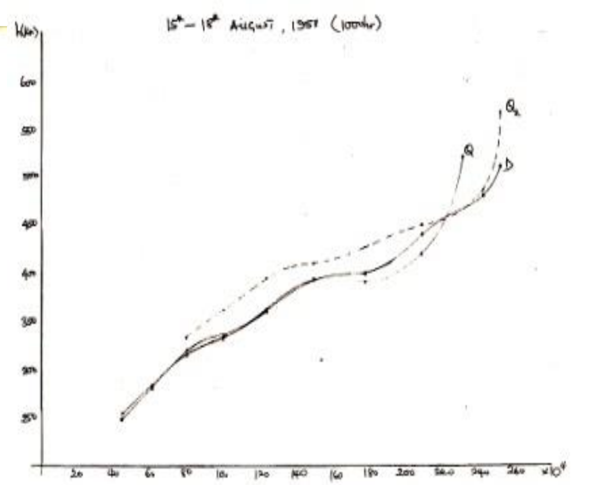


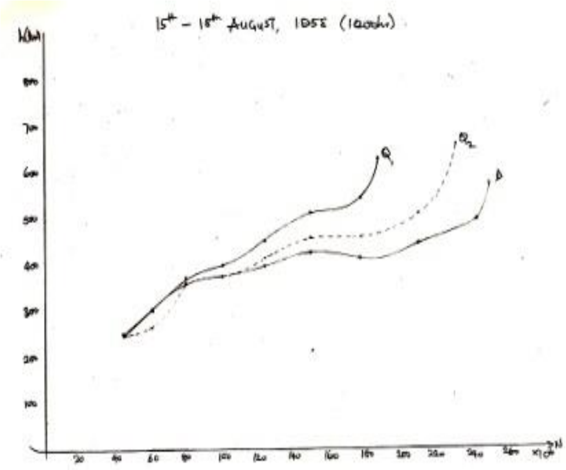


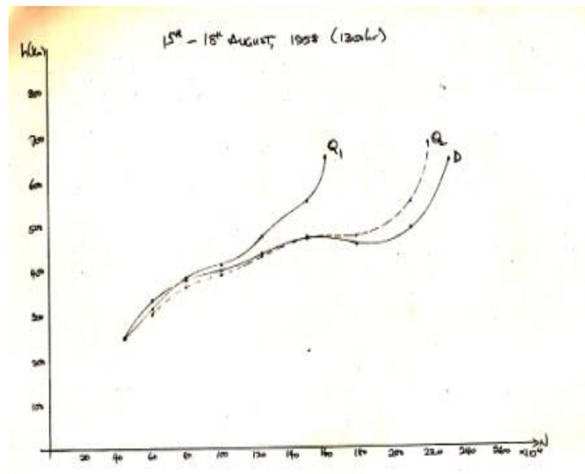


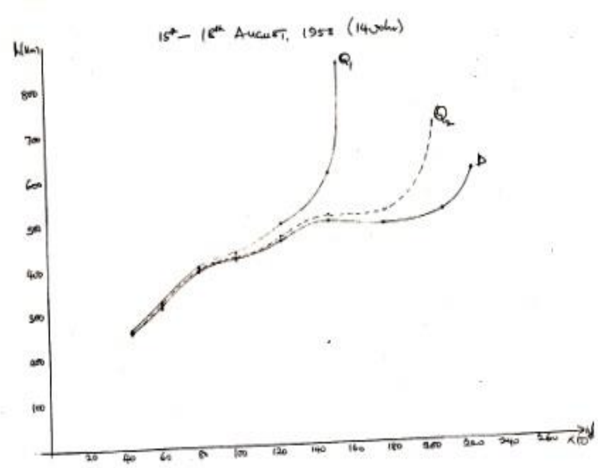


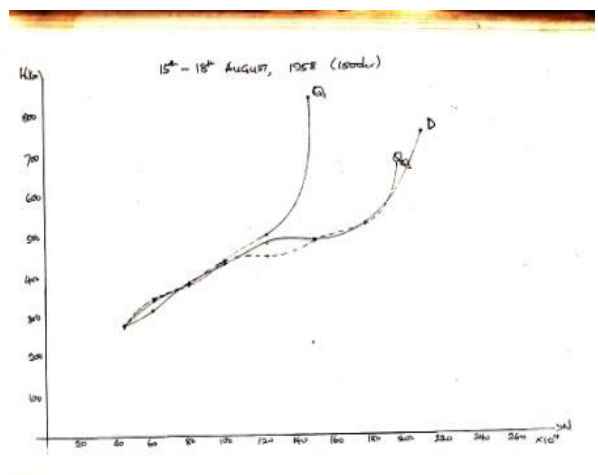


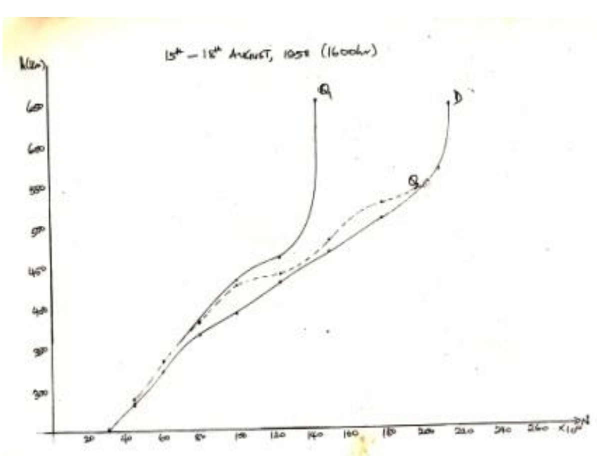


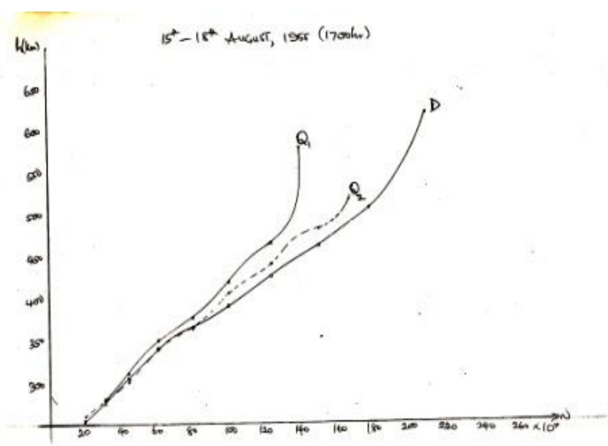


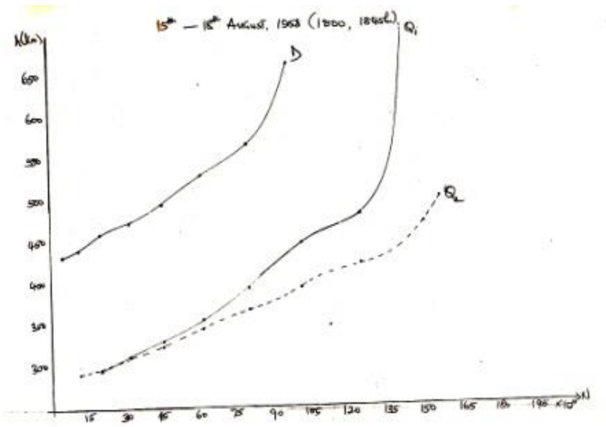












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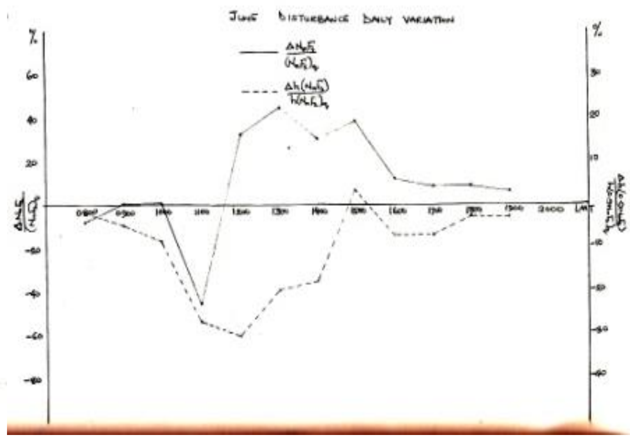

JUNE DISTURBANCE DAILY VARIATION
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L.M.T

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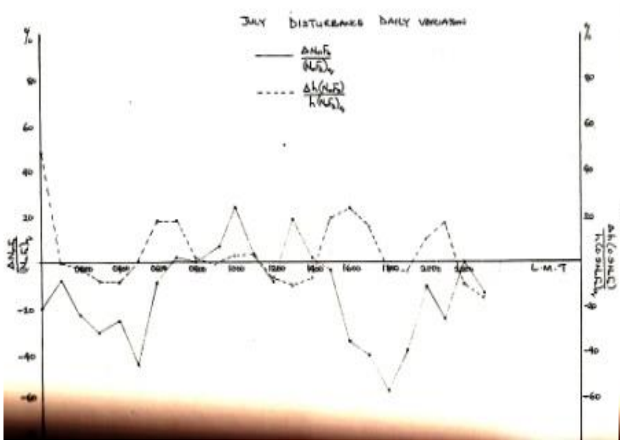

JULY DISTURBANCE DAILY VARIATION
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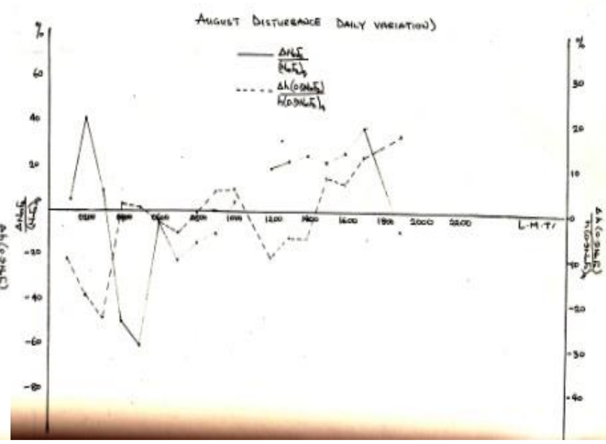

AUGUST DISTURBANCE DAILY VARIATION
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L.M.T

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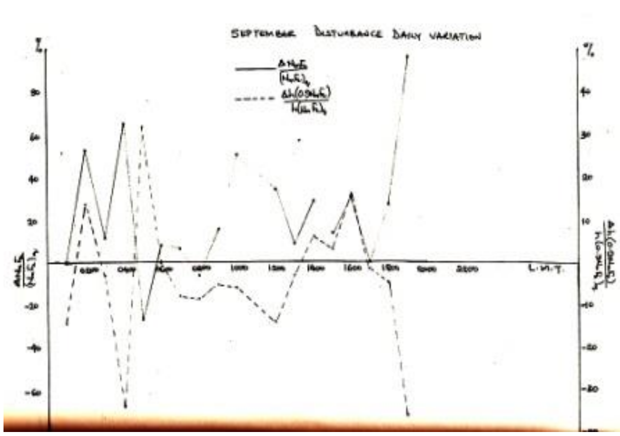

SEPTEMBER DISTURBANCE DAILY VARIATION
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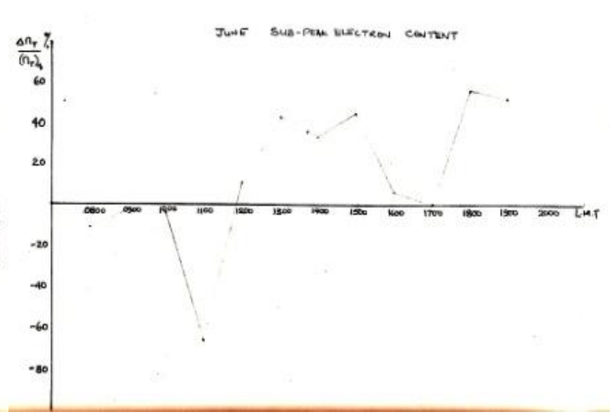
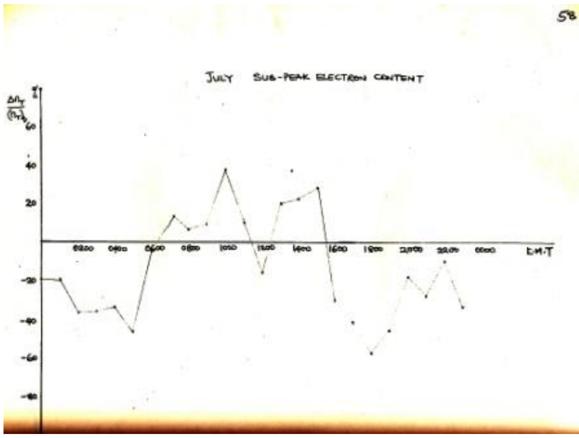


JUNE SUB-PEAK ELECTRON CONTENT
L.M.T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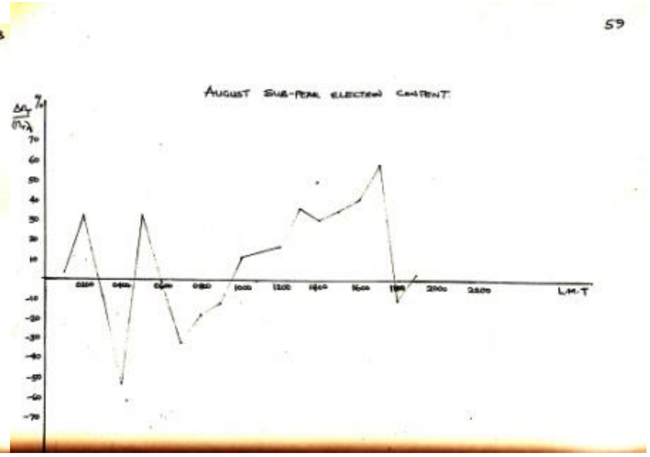
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AUGUST SUB-PEAK ELECTRON CONTENT
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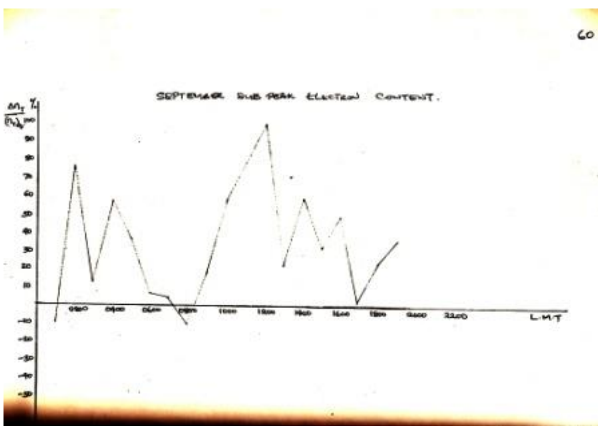
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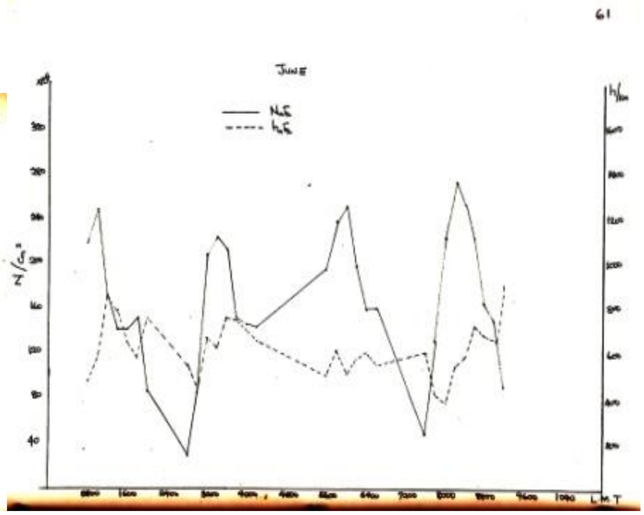
L.M.T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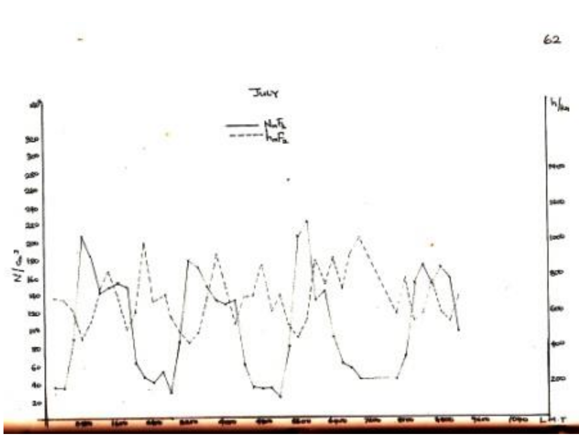
JUNE
L.M.T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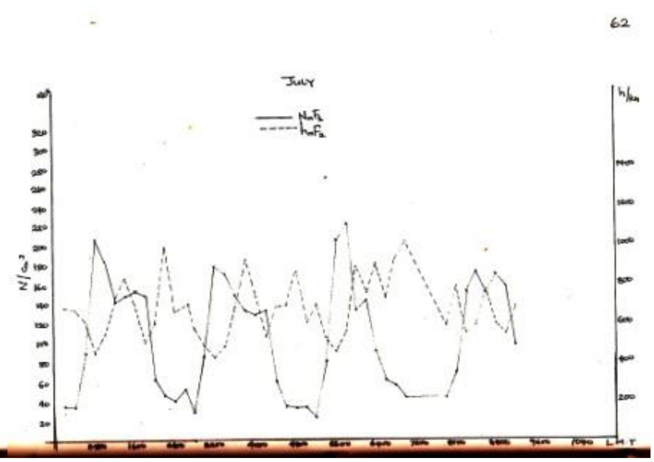
JULY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JULY
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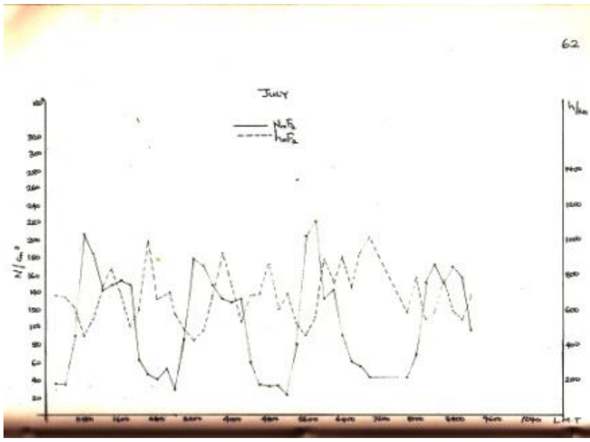
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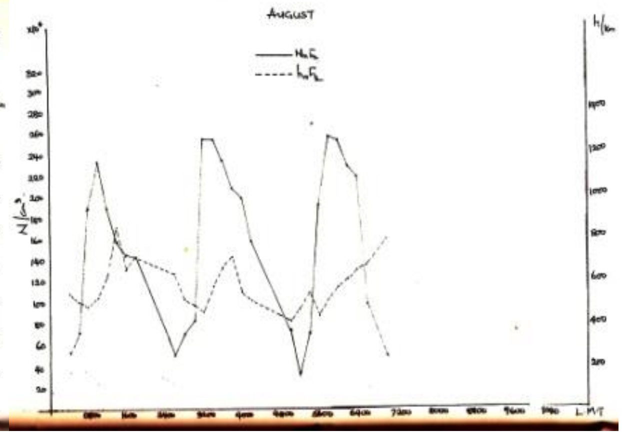
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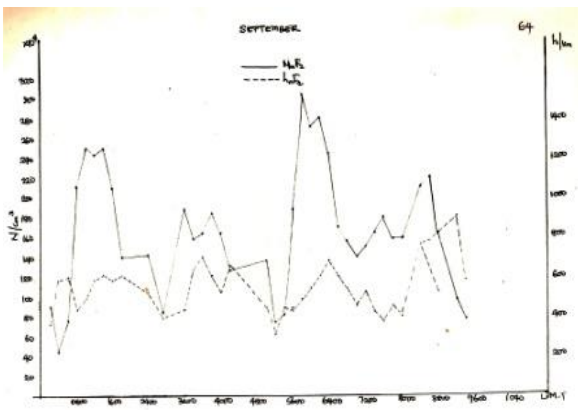
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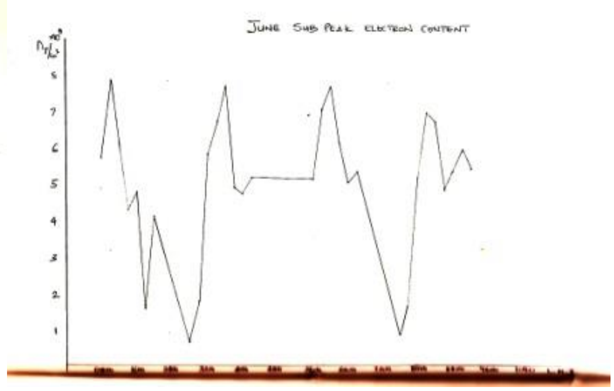
JUNE SUB PEAK ELECTRON CONTENT

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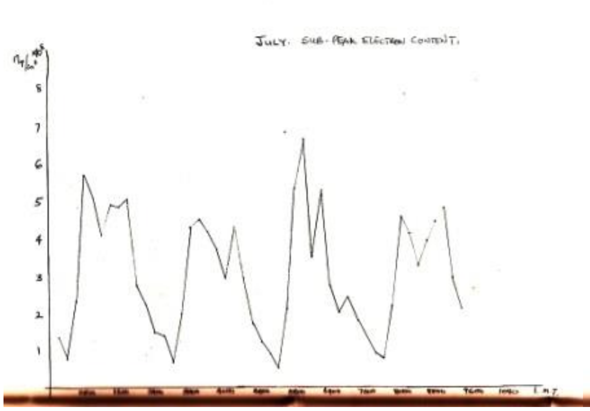
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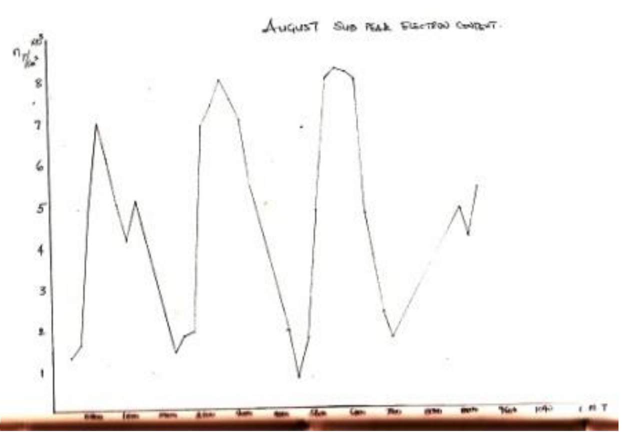
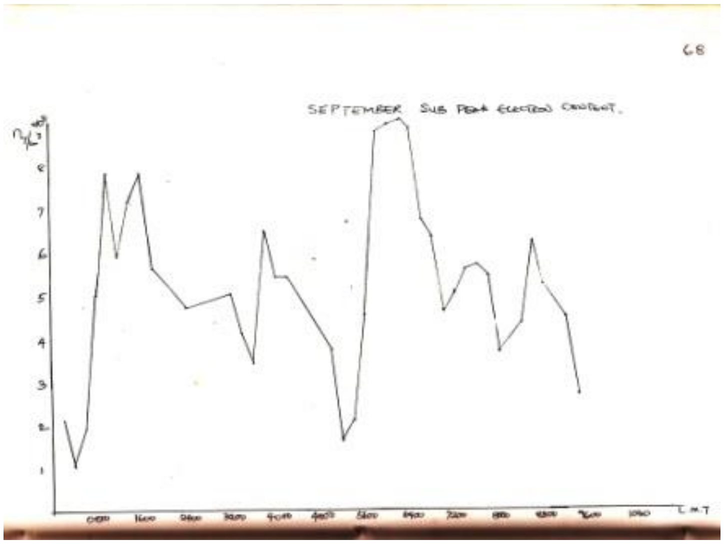

AUGUST SUB PEAK ELECTRON CONTENT.



CONCLUSION

F_2 disturbance on the equatorial zone can be interpreted as the effect of the vertical drift on the electrons set up by electric field deduced from the magnetic disturbance daily variation. In daytime, positive storm is caused by upward drift of ionization as a result of electro dynamic drift. The negative storm is caused by an increase rate of recombination brought about by mixing of atmospheric waves. The reduction of n_T and NmF_2 during magnetic storms is not entirely due to redistribution of ionization. A substantial part is due to removal of ionization at all levels possibly due to associated increased loss rate.

Finally, the discovery that the geomagnetic Ds variations are different for ionospherically positive and negative storms support the drift theory which also attributes F region storm to electromagnetic movement caused by electric currents.

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