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4. *The Decrease of the Electrical Conductivity in the Ionosphere Associated with the Solar Eclipse*

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As mentioned in the last section, the magnetic condition of the earth's magnetic field on 21 June was most quiet, we can estimate the diurnal variation of the electrical conductivity of east-west direction of the ionosphere above Ceylon using the record of horizontal component of 21 June which is shown in the end of this volume. Table 2 shows the value of horizontal component of 21 June of every thirty minutes.

Table. 2. Values of ΔHc (in γ). Hc : + 40141 γ

T	00.00	00.30	01.00	01.30	02.00	02.30	03.00	03.30	04.00	04.30	05.00	05.30
ΔHc	0	0	3.0	3.5	5.0	5.0	5.0	5.0	4.5	3.5	3.0	3.5
T	06.00	06.30	07.00	07.30	08.00	08.30	09.00	09.30	10.00	10.30	11.00	11.30
ΔHc	6.0	6.5	7.5	12.0	16.0	23.0	31.5	38.0	48.0	57.0	65.5	66.5
T	12.00	12.30	13.00	13.30	14.00	14.30	15.00	15.30	16.00	16.30	17.00	17.30
ΔHc	65.0	64.5	64.0	57.0	46.0	37.0	27.0	16.5	4.5	0	−2.5	−2.5
T	18.00	18.30	19.00	19.30	20.00	20.30	21.00	21.30	22.00	22.30	23.00	23.30
ΔHc	−2.5	−2.0	−1.5	−1.0	0	1.0	1.0	—	1.5	1.5	−2.5	−3.5

According to M. Hasegawa and H. Maeda (1), the current intensity of electrical current, flowing in the ionosphere, by which the daily variation of the earth's magnetic field is caused, is expressed as follows

$$I_x = K_x E_x , \qquad I_y = K_y E_y , \tag{1}$$

where K_x, K_y, E_x, and E_y are the height integrated conductivity (north-south, east-west directional), and the the electric field (N-S, E-W) respectively,
Let I denote the total current flowing E-layer (assumed to be a thin layer), then the magnetic variation observed below this layer is approximately given by

$$\Delta H = 2\pi I . \tag{2}$$

ΔH is the daily magnetic variation at the earth's surface produced by external cause. Since the ionospheric current pattern is not an infinite sheet and is not always uniform and ΔH at the earth's surface is produced not only by external cause but also by internal cause, we must put

$$\Delta H = 2\pi k I , \tag{3}$$

where k is the correction factor nearly equal to unity.

Then we have

$$I_y(t) = K_y(t)\, \Delta E_y(t)\,, \tag{4}$$

If we put

$$K_y(t) = K_0 \{1 + \gamma \cos(t+\delta_1) + \delta_2 \cos(2t+\delta_2) + \cdots\cdots\} = K_0 \psi(t)\,, \tag{5}$$

then

$$\Delta H_x(t) = \Delta H'_x(t) \cdot \psi(t)\,. \qquad \text{where } \Delta H'_x = 2\pi k K_0\, \Delta E_y\,, \tag{6}$$

We can write

$$\begin{aligned} \Delta H_x(t) &= C_0 + \Sigma\, C_n \sin(nt + \varepsilon_n) \\ &= \{\Sigma\, C_n \sin(nt + \delta)\} \cdot \{1 + \Sigma\, \gamma_n \cos(nt + \delta_n)\} \end{aligned} \tag{7}$$

Since the coeficients C_0, C_1, C_2, ..., ε_1 ε_2, ..., is obtained by the observed curve of ΔH_x, We can get these coeficients. H. Maeda obtained the conductivity K_y by this method, that is

$$K_y = K_0 (1 - 1.15 \cos t + 0.42 \cos 2t)\,. \tag{8}$$

Using the same method we estimate the electrical conductivity of the current flowing in the layer (E-layer) above Ceylon. Thus obtained result is expressed as following equation or Table 3

$$K_y = K_0 (1 - 1.30 \cos + 0.63 \cos 2t)\,. \tag{9}$$

Fig.24 shows this diurnal variation of the electrical conductivity on 21 June. It is clear this diurnal variation of K_y is quite similar to that of obtained by H. Maeda who get the result from the analysis of the all magnetic quiet days during the years of one sunspot cycle, 1922–33, at Huancayo Therefore, it is clear that the magnetic condition of 21 June, is quite quiet.

Next, we estimate the decrease of the electrical conductivity in the ionosphere due to the decrease of ionising ability during the eclipse time, useing the data of the geo-magnetic field. The difference of the value of the horizontal component of the earth's magnetic field between the eclipse day and 21 June, at the time of passage of solar eclipse is calculated by the records of magnetic field which is shown at the end of this

Table. 3. K (t)/K (noon)

T	12	13	14	15	16	17	18	19	20	21	22	23
K(t)/K(noon)	1.00	0.96	0.83	0.65	0.45	0.27	0.13	0.04	0.01	0.03	0.06	0.10

volume. Fig.25 and Table 4 show the value of this difference which is considered as the effect of solar eclipse. As this figure shows, the value of difference, that is the effect of solar eclipse, is yet continued about one hour even when the eclipse is ended at Ceylon. This may be caused by the distorted current of S_q current which is produced by the decrease of conductivity of the ionosphere in the eclipsed area neighbouring Ceylon as described in the last section. In order to avoid this so-called after effect of the eclipse, we calculate the value of propotion of this diffe-

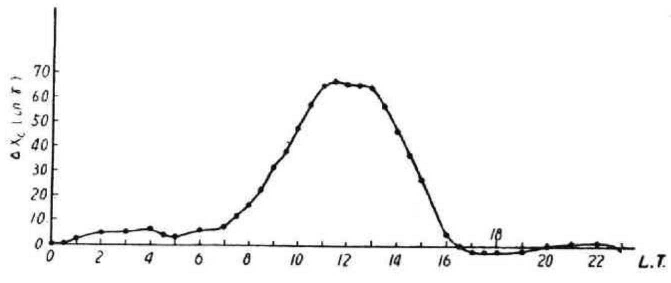

Fig. 24. Variation of the Magnetic N-S Comporent (upward : N-direction) on 21, June, 1955.

rence value due to eclipse to the amplitude of daily variation of 21 June at respective time (Table 4) and reduced this value from each value of difference, so as to the difference or the effect of the eclipse becomes zero at the time of the end of the

Table. 4. Values of ΔH_0 and $\Delta H_0/\Delta H_c$ (in %)

T	07·00	07·15	07·30	07·45	08·00	08·15	08·30	08·45	09·00	09·15	09·30	09·45
ΔH_E	10.0	11.0	12.5	12.5	12.5	13.0	14.0	18.0	22.0	26.0	31.0	38.0
ΔH_c	7.5	9.5	12.0	14.0	16.0	19.5	23.0	27.0	31.5	34.5	38.0	43.0
ΔH_0	2.5	1.5	0.5	−1.5	−3.5	−6.5	−9.0	−9.0	−9.5	−8.5	−7.0	−5.0
$\Delta H_0/\Delta H_c$	33.3	15.8	4.2	−10.7	−21.9	−33.33	−39.1	−33.0	−30.2	−24.6	−18.4	−11.6

T	10·00	10·15	10·30	10·45	11·00
ΔH_E	44.0	51.0	57.0	61.0	65.5
ΔH_c	48.0	52.5	56.5	61.0	65.5
ΔH_0	−4.0	−1.5	0.5	0	0
$\Delta H_0/\Delta H_c$	−8.3	−2.9	0.9	0	0

ΔH_E : Eclipse day

ΔH_c : 21 June

ΔH_0 : Difference value

Table. 5. Values of ΔH

T	07·00	07·15	07·30	07·45	08·00	08·15	08·30	08·45	09·00	09·15	09·30
ΔH	2.5	1.5	0.5	−1.5	−3.5	−6.5	−9.0	−7.7	−6.9	−4.5	0

eclipse at Ceylon (Table 5 or Fig.27). This rough approximation can be adopted because the eclipse is occurred near the geomagnetic equator and so the eclipsed area passes on the zone of nearly parallel sheet (E-W direction) of the S_q current. Fig. 24 and Table 4 show this calculated value of the effect of solar eclipse on the earth's magnetic field. The horizontal intensity is decreased about 10% at maximum phase of the eclipse. Now we estimate the decrease of the electrical conductivity in the ionosphere at the time of eclipse as folllows.

We suppose the uniform current (its intensity I_C) is flowing in the E–W direction in the ionosphere, which has uniform conductivity K_C, and the circular area of the electrical conductivity K_E is setted up in this sheet, then the electrical current I_E, which flows in this circular area, is given readily as follows (this model is similar to that of S. Chapman (2))

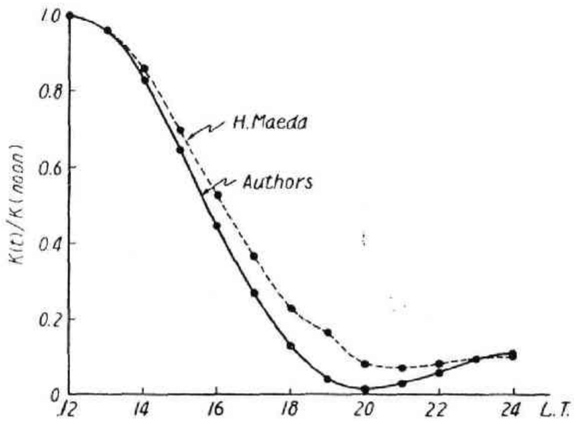

Fig. 25. Daily Variation of the Electrical Conductivity estimated from the Daily Magnetic Variation

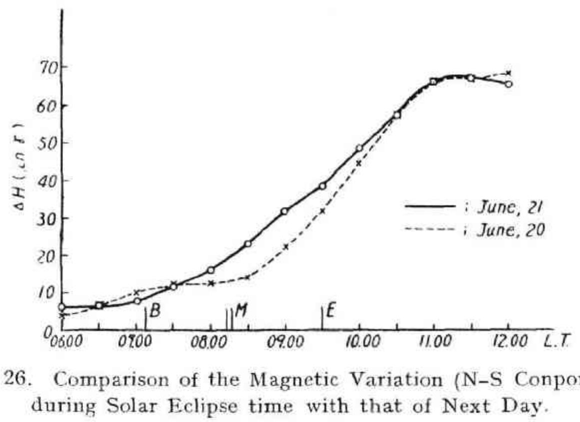

Fig. 26. Comparison of the Magnetic Variation (N-S Conponent) during Solar Eclipse time with that of Next Day.

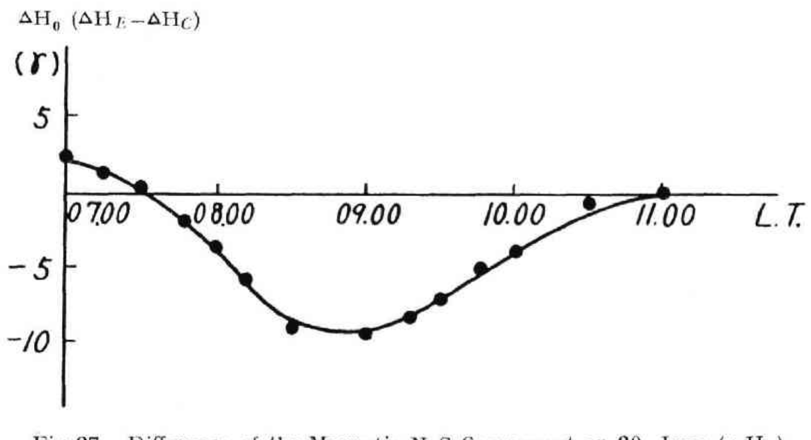

Fig 27. Difference of the Magnetic N-S Component on 20, June ($\triangle H_E$) and 21, June ($\triangle H_C$).

$$I_E = \frac{2K_E}{K_c+K_E} I_c \,. \tag{10}$$

Forfhe magnetic field of N–S component produced by the electric current flowing in the lower part of the ionosphere, we obtain approximately

$$\varDelta \mathrm{H}_c = 2\pi I_c \tag{11}$$

and

$$\varDelta H_E = 2\pi I_E \tag{12}$$

$$\therefore \quad \varDelta H_E - \varDelta H_c = \varDelta H = 2\pi\,(I_E - I_c)\,, \tag{13}$$

if we put

$$K_E = \frac{K_c}{n} \qquad (\mathrm{n};\ \text{positive integer})\,, \tag{14}$$

then we have

$$n = \frac{\varDelta H_c - \varDelta H}{\varDelta H_c + \varDelta H} \tag{15}$$

We can obtain the value n by time to time of the eclipse day by this method. Table 6 and Fig.29 show this value of K_E/K_C at each time of the eclipse. As the Fig.29 or Table 6 shows, we obtained the distribution of the changes of the electrical conductivity in the ionosphere associated with the eclipse. It is seen that the electrical conductivity is decreased about 46% smaller than that of normal day at the center of the eclipse area. This changes of the conductivity is approximately represented by the parabolic distribution with the eclipse area. The ionospheric data at Kodaikanal, India which is situated near the total eclipse zone of this solar eclipse is shown in Table 6 and the electron density of E - layer is decreased about 50% smaller than

Table. 6. Values of K_E/K_c

T	07·00	07·15	07·30	07·45	08·00	08·15	08·30	08·45	09·00	09·15	09·30
ΔH_c	7.5	9.5	12.0	14.0	16.0	19.5	23.0	27.0	31.5	34.5	38.0
ΔH	2.5	1.5	0.5	−1.5	−3.5	−6.5	−9.0	−7.7	−6.9	−4.5	0
$\Delta H_c+\Delta H$	10.0	11.0	12.5	12.5	12.5	13.0	14.0	19.3	24.6	30.0	38.0
$\Delta H_c-\Delta H$	5.0	8.0	11.5	15.5	19.5	26.0	32.0	34.7	38.4	39.0	38.0
n	0.5	0.73	0.92	1.24	1.56	2.00	2.30	1.80	1.56	1.30	1.00
K_E/K_c	2.00	1.37	1.07	0.81	0.64	0.50	0.43	0.56	0.64	0.77	1.00
K_E/K_0	1.00	0.79	0.64	0.54	0.48	0.46	0.48	0.54	0.64	0.79	1.00

Table. 7. Values of f_0E (in M.C.) at Kodaikanal,

20, June, 1955.

T	07·00	07·30	08·00	08·30	09·00	09·30	10·00	10·30	11·00
f_0E	2.30	2.30	2.00	2.80	(3.30)	3.48	3.60	N	3.70

21, June, 1955

T	07·00	07·30	08·00	08·30	09·00	09·30	10·00	10·30	11·00
f_0E			(2.90)	3.10	3.30	3.50	3.55	3.55	3.60

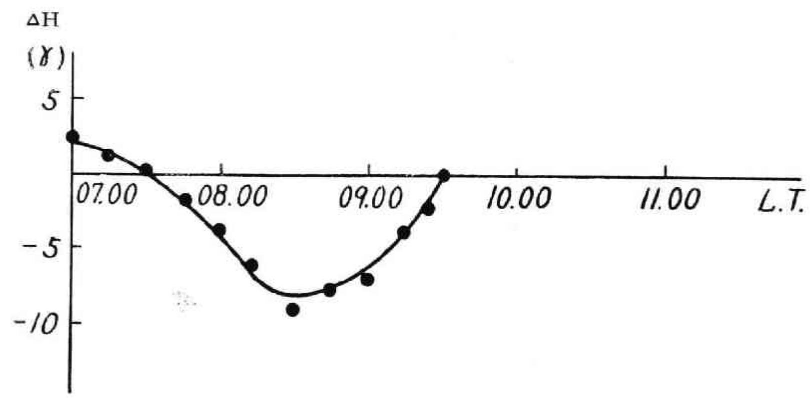

Fig. 28. Corrected Difference Curve of Fig. 27.

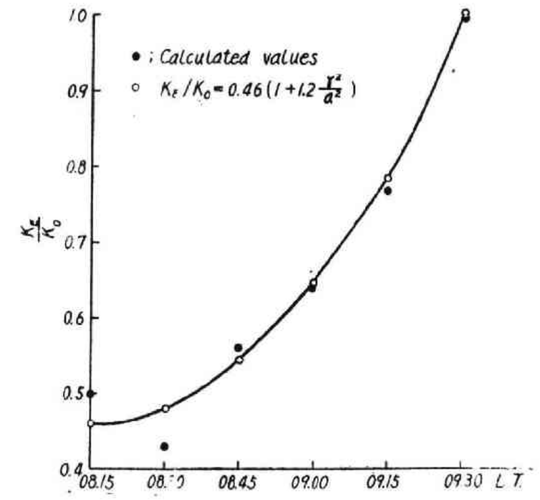

Fig. 29. Change of the Electrical Conductivity during the Solar Eclipse Time. It's Calculated Value using the Magnetic Data is Represented Approximately by the Eq. $K_E/K_O = 0.46\ (1+1.2\ r^2/a^2)$, where a is the Effective Radius of the Shadowed Area and $r \leqq a$.

that of 21 June. It may be considered that the decrease of conductivity is proportional to that of electron density, so the above results are good agreement each other.

It is made clear that the effect of solar eclipse on the geomagnetic field is caused by the decrease of electrical conductivity of the ionospher of the eclipsed area and so by the modification of S_q current which passes the eclipsed area of the ionosphere. Finally we want to express our heaoty thanks to Dr. A. K. Das, Dy. Director of Kodai-Kanal observatory who gave us the ionospheric data taken at Kodai-Kanal.

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