The E Region of the Ionosphere During the Total Solar Eclipse of October 1, 1940

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It is pointed out that ionospheric observations during the total solar eclipse of October 1, 1940, visible in northern Brazil, may provide data for an exacting test of the theory of solar radiation origin of the E region and may yield a precise value of the ionic recombination coefficient α that occurs in the theory. To this end E region ionization curves are worked out for various assumed values of α during the eclipse.

LET y_m be the maximum-with-height value of the equivalent electron density of the E region of the ionosphere and let the recombination coefficient α of the ionization be proportional to y_m^2. In the preceding paper[1] it was shown that the observed variation of y_m during the daylight hours was in close agreement with the theory that the ionization was caused by solar radiation absorbed exponentially in a relatively quiet terrestrial atmosphere. A value for α of 2×10^{-8} was indicated but the accuracy of the experimental data did not preclude the possibility of an even higher value. It is doubtful that a more exact value of α can be obtained from diurnal measurements in view of the relatively slow change in solar radiation intensity due to the diurnal variation of solar zenith angle. During an eclipse of the sun the solar radiation intensity changes rapidly and it appears that y_m data obtained at a station in the path of totality may offer a more precise determination of α and a more exacting test of the theory. Although ionosphere observations have been made during epochs of solar eclipses,[2] there exist no measures of y_m by a station in the path of totality.

A total eclipse of the sun occurs on October 1, 1940, under circumstances favorable to an ionosphere experiment. The complete elements of the eclipse will be published soon by the United States Naval Observatory. The central line of totality runs along the northern edge of Brazil.[3] At Pernambuco, Brazil, totality occurs at about 10 A.M., local time, of duration about 5 minutes, the solar zenith angle being about 35°.

[1] E. O. Hulburt, Phys. Rev. **55**, 639 (1939).
[2] S. S. Kirby, T. R. Gilliland and E. B. Judson, Nat. Bur. Stand. J. Research **16**, 213 (1936), and references *infra*.
[3] L. T. Comrie, Roy. Astron. Soc., M. N. **93**, 181 (1932–33).

In Fig. 1 are given y_m curves for the period of the eclipse calculated for various values of α. In order to make the calculations, eclipse conditions were assumed that approximate those of the actual eclipse. Exact calculations for the actual eclipse can be made when the location of the observing station is known. Assume that the station is at latitude 8° S and longitude 35° W, as near Pernambuco, and that the first, second, third and fourth contacts occur at 9, 10, 10.04 and 11.04 A.M., local time, respectively. Since the apparent diameters of the sun and moon are approximately equal and since the moon moves uniformly across the sun, the fraction f of the exposed disk of the sun is expressed as a function of the time t seconds by

$$f=1-(2/\pi)\{\cos^{-1} T-T(1-T^2)^{\frac{1}{2}}\}. \qquad (1)$$

Between first and second contacts, t is measured from the first contact, $T=1-t/3600$; and between second and third contacts, t is measured from the third contact, $T=t/3600$. Here t refers to the ionospheric level under investigation and not to the surface of the earth.

Let q ion-electron pairs sec.$^{-1}$ cm^{-3} be the rate of production of ionization at the y_m level and ζ be the zenith angle of the sun. From Eqs. (2), (3) and (4), reference 1,

$$q=q_0 \cos \zeta, \qquad (2)$$

where q_0 is the value of q for the sun overhead. In general, from Eq. (16), reference 1,

$$dy_m/dt=-\alpha y_m^2+q. \qquad (3)$$

On a day with no eclipse, from (2) and (3),

$$dy_m/dt=-\alpha y_m^2+q_0 \cos \zeta, \qquad (4)$$

and during the eclipse, from (1), (2) and (3)

$$dy_m/dt=-\alpha y_m^2+fq_0 \cos \zeta, \qquad (5)$$

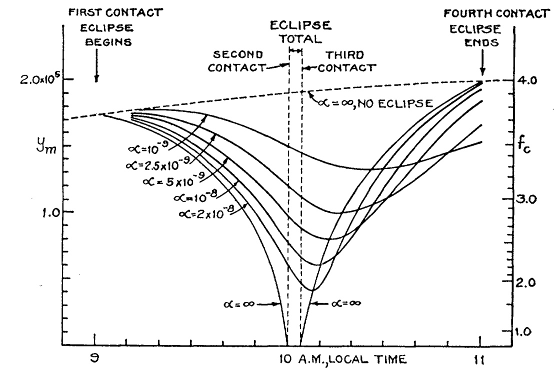

FIG. 1. Theoretical ionization of E region at Pernambuco, Brazil, during the eclipse of October 1, 1940.

on the assumption that the intensity of the ionizing radiation is proportional to f.

For α very great, practically infinite, the ionization is approximately in equilibrium with the radiation which produces it and $dy_m/dt=0$. Eqs. (4) and (5) become, respectively, for no eclipse

$$y_m=[(q_0 \cos \zeta)/\alpha]^{\frac{1}{2}}, \tag{6}$$

and during the eclipse

$$y_m=[(fq_0 \cos \zeta)/\alpha]^{\frac{1}{2}}. \tag{7}$$

In Fig. 1 y_m from (6) and (7) is plotted in the two curves marked $\alpha=\infty$; the constant q_0 is adjusted to make $y_m=2\times10^5$ at 11 A.M., which is probably near to the actual value for the E region. The other curves of Fig. 1 were worked out from (5) with the various values of α designated; for each curve q_0 was chosen to give $y_m=1.74\times10^5$ at the beginning of the eclipse. The method of determining the curves has been described[1] and consisted in following graphically the course of dy_m/dt step by step. The datum observed by an ionosphere station is the critical frequency f_c for each region of ionization, where for the ordinary ray

$$f_c^2=ye^2c^2/\pi m; \tag{8}$$

e and m refer to the electron and c is the velocity of light. A scale of f_c in megacycles per second is marked on the right of Fig. 1.

From Fig. 1 it appears that measurements of f_c during the eclipse might determine α with some degree of precision. It would be important that the E region during the eclipse be free from sporadic effects and magnetic disturbance. The assumption in (5) of uniformity of ionizing radiation over the solar disk must be borne in mind. Near the edge of the disk the assumption may fail. In any case analysis of the observations might give information about the intensity distribution over the face of the sun. As said before, if observations are made by an ionosphere station in the path of totality, exact calculations similar to those of Fig. 1 can be made referring to the location of the station. The foregoing discussion has been directed to consideration of the E region, but with appropriate changes it applies equally well to the other regions of the ionosphere.