Eclipse Effects in the Ionosphere *

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It is concluded from measurements of virtual heights and critical ionization frequencies of the various regions of the ionosphere which were made during two solar eclipses at Deal, New Jersey, that ultra-violet light is an important ionizing agency in the E, M, F_1, and F_2 regions.

AS a result of pulse measurements made at Deal, New Jersey, during the partial eclipse of the sun February 3, 1935,[1] and during the total eclipse of the sun of August 31, 1932,[2] we now have data which show that the passage of the moon's shadow across the earth is accompanied by a decrease in ionization in four of the ionized regions of the ionosphere (E, M, F_1 and F_2).[3]

During the 1932 eclipse the ionic density in the E and F_1 regions was found to decrease, with the maximum effect occurring shortly after the eclipse maximum. Since the ionization in these two regions ordinarily changes uniformly with time, and since the variations observed during the eclipse were much larger than normal variations, we believe that the decrease in ionic density was actually caused by the eclipse. As regards the changes observed in the F_2 region, our 1932 results were not conclusive because the maximum effect in this region did not coincide with the eclipse but occurred somewhat later. The ionic density in this region is known to fluctuate on at least some non-eclipse days and did in fact undergo comparable variations on several occasions during the two days preceding and the two days following the eclipse. Other observers have reached the same conclusions as regards the F_2 region during the 1932 eclipse from their own data.[4]

The data from which our conclusions were drawn are shown in Fig. 1.

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[1] Letter to *Nature*, vol. 135, p. 393; March 9, 1935.

[2] Mention has already been made of the results of our 1932 eclipse experiments in the following publications:

Science, November 11, 1932; *Proc. Fifth Pacific Science Congress*, vol. 3, pp. 2171–2179, 1934; *Nature*, September 30, 1933; *Bell Lab. Record*, March, 1935.

The data have never been published and we are therefore including some of it in this paper as it may be of interest to other investigators in this field.

[3] M refers to the intermediate region between E and F_1.

[4] Kirby, Berkner, Gilliland, and Norton, *Proc. I. R. E.*, vol. 22, pp. 246–265, February, 1934; Henderson, *Canadian Jour. Res.*, January, 1933.

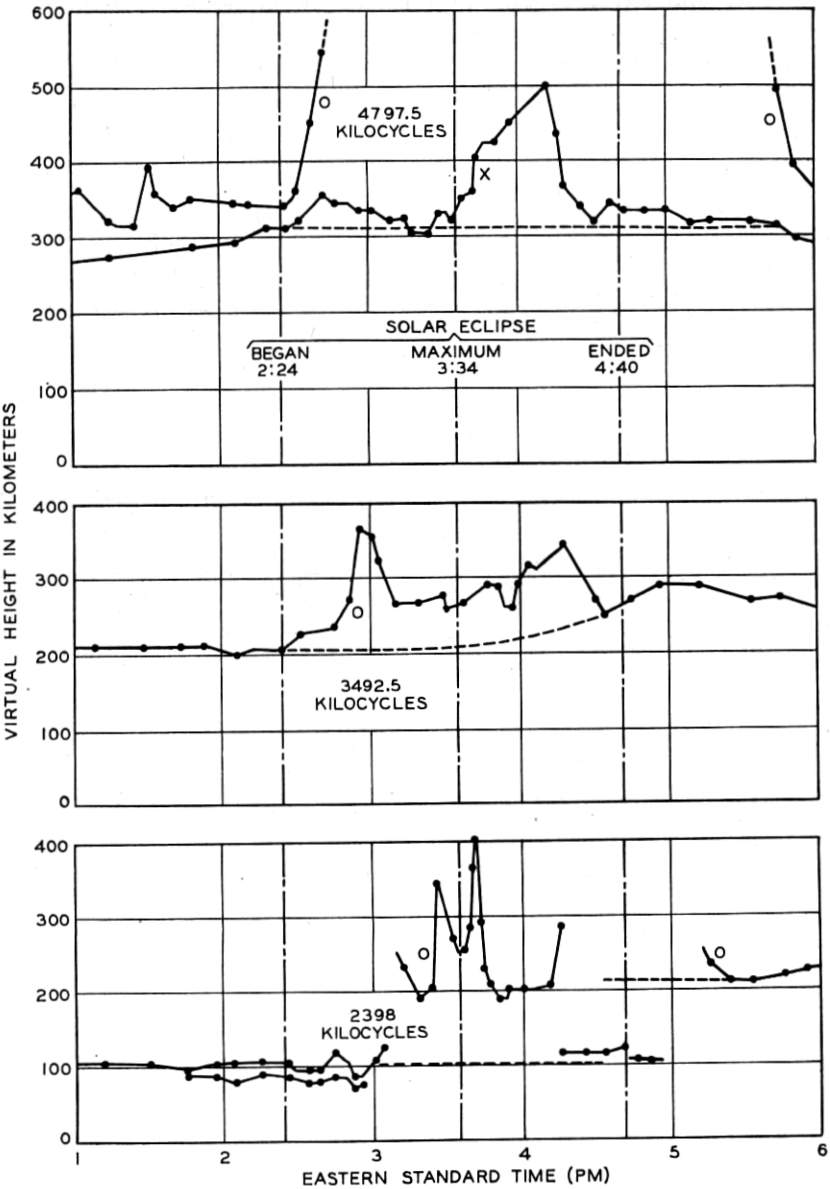

Fig. 1—Virtual height values during the total eclipse of August 31, 1932.

The double maximum in virtual height with a minimum between for 2398 and 3492.5 kilocycles [5] is interpreted by us to have been caused by a decrease in ionic density in the F_1 region, which resulted in a change in reflection from the F_1 to the F_2 layer during the central part of the eclipse.

From the curves of Fig. 1, it is possible to plot the virtual height contour map shown in Fig. 2. Since we know as a result of data taken

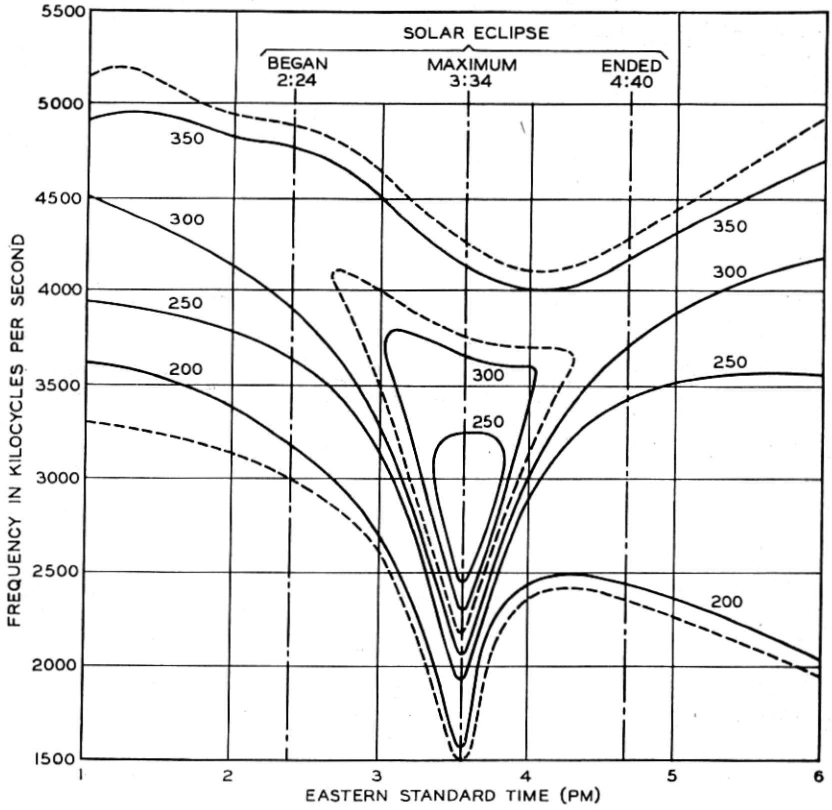

Fig. 2—Virtual height contour map drawn from data for Fig. 1, for August 31, 1932.

on several hundred days that the *X*-component curve in Fig. 1 for 4797.5 kilocycles is nearly equivalent to the *O*-component [6] curve for a frequency approximately 750 kilocycles lower (i.e., 4050 kilocycles),

[5] Mimno and Wang, *Proc. I. R. E.*, vol. 21, pp. 529–545, April, 1933, and Kenrick and Pickard, *Proc. I. R. E.*, vol. 21, pp. 546–566, April, 1933, obtained similar double maximum curves.

[6] The expressions "*O*-component" and "*X*-component" are used in place of the terms "ordinary ray" and "extraordinary ray" used by other writers.

there are in effect *O*-component curves for four different frequencies available for plotting the contour map. The dotted lines represent regions of maximum ionization. These curves show in a rather striking manner the sharp decrease in ionization of the E and F_1 regions near the time of the eclipse maximum.

The uncertainty of the 1932 results as regards the F_2 region led us to concentrate our efforts on this region during the 1935 eclipse. Improved technique now made it possible to measure the critical ionization frequencies directly instead of making virtual height measurements on fixed frequencies as had been done during the 1932 eclipse. The critical frequencies for the E and M regions were measured in addition to those for the F_2 region.

We found that this eclipse was accompanied by a decrease in the maximum ionic density in all three regions and that the minimum ionization occurred at or very shortly after the eclipse maximum. The percentage decrease was progressively greater from the lowest to the highest region, being approximately twenty per cent for the E region, twenty-two per cent for the M region, and twenty-five per cent for the F_2 region.

Some such progressive change might be expected from the fact that the eclipse had a magnitude of forty per cent at the ground and approximately forty-three per cent in the F_2 region (250 kilometers over Deal). These magnitudes are in terms of the sun's diameter, and on the basis of eclipsed area these figures become twenty-nine and thirty-one per cent, respectively.

Figure 3 gives the critical ionization frequencies for the three days on which data were obtained. The curves for the E and M regions are for the *O*-component while the curves for the F_2 region are for the *X*-component. For the *O*-component, the ionic density, N, is proportional to f_c^2, where f_c is the critical ionization frequency, while for the *X*-component curve in Fig. 3, N, is proportional to $(f_c - 750\text{ kc.})$.[2]

The decreases in ionic density of the various regions may be compared with a fifty to sixty per cent decrease in the E region ionization during the eclipse of August 31, 1932, when the eclipse magnitude was ninety-five to one hundred per cent.

The 1935 measurements give a more definite synchronism than those of 1932, between the eclipse occurrence and the time of decrease in ionic density of the F_2 region.

In view of the variable nature of the F_2 region, it is a possibility that the decrease in ionic density at the time of the eclipse was a mere coincidence and was actually due to some noneclipse agency. We believe that this was not the case and that the decrease in F_2 ionization

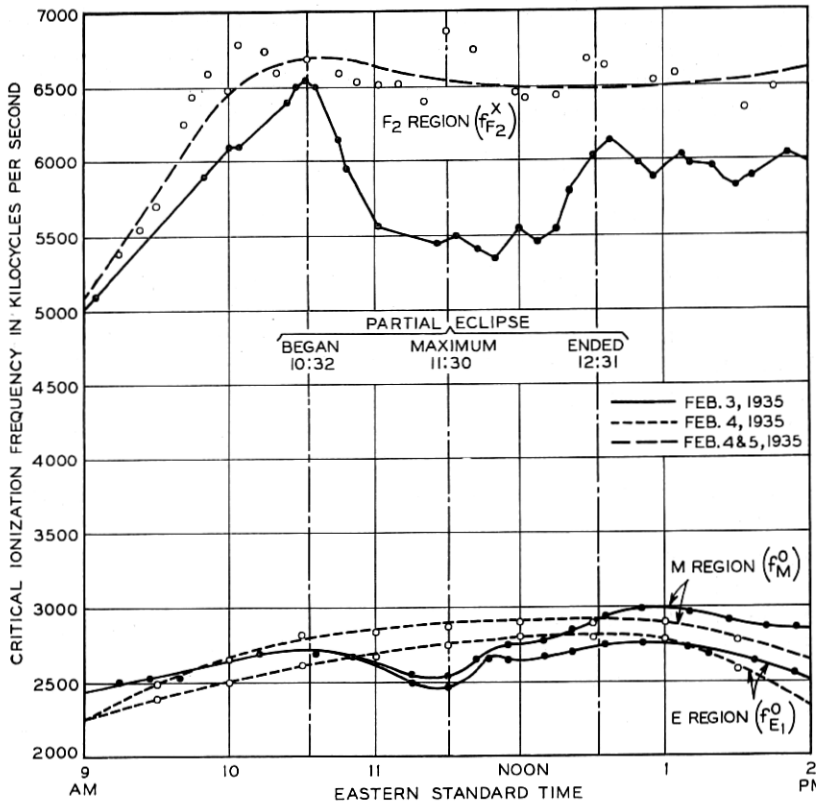

Fig. 3—Critical ionization frequencies during the partial eclipse of February 3, 1935

was a bona fide eclipse effect, as the decrease began within a few minutes after the first contact, and the density attained its lowest value shortly after the maximum of the eclipse and recovered to a more or less constant higher value a few minutes after the last contact. At no time during these measurements on the eclipse day or the days after was there any other variation of a comparable magnitude.

These results therefore indicate that ultraviolet light [7] is an important ionizing agency in the E, M, F_1 and F_2 regions of the ionosphere.

[7] While ultraviolet light is probably the ionizing agency responsible for the effects noted, any other solar emanation which travels substantially at the velocity of light, should not be precluded from consideration. *See* E. A. W. Müller, *Nature*, February 2, 1935, who suggests Roentgen type radiation.