Ozone Measurements during Solar Eclipse

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Abstract

Ozone measurements during a solar eclipse at Bunia Observatory, Belgian Congo, showed an increase by about 4 % of total amount from 20 minutes before the maximum phase with its highest value shortly after it.

The variations of ozone amount from day to day in the equatorial regions are very small so that it seems to be promising to carry out investigations which aim at finding variations of a regular or specific kind. Therefore measurements at short intervals were carried out at Bunia, Geophysical Observatory of the Meteorological Service of the Belgian Congo, on October 2nd, 1959, where the solar eclipse was partial, as well as on the days before and afterwards.

The results obtained with the Dobson spectrophotometer are presented in the following. The first contact of the moon occurred at 14.50 hours apparent time, while the maximum phase of the eclipse was about 80 % at 16.03 hours. The measurements could not be extended until the last contact which occurred at 17.12, only half an hour before sunset.

During the major part of the observation period the sky was rather clear. Only thin cirrus clouds appeared from about 15.20. Direct sun measurements could be made from 14.24 hours apparent time until 17.11 hours, except for an interval between 16.38 and 17.07 hours when a stratocumulus layer covered the sun and part of the sky. Additional measurements of the zenith sky were made in a close sequence from 06.48 hours in the morning until 13.42 in the afternoon, in the morning on altocumulus and towards noon on altocumulus and/or cumulus.

Likewise frequent measurements were taken on October 1st, mainly on the direct sun, and on October 3rd, mostly on the zenith sky, in order to get a mean curve of non-affected ozone values. Further ozone results of September 28th—30th, and October 4th, 5th, and 7th were used to form a mean curve for $\mu =$ 3 and 2 in the morning and afternoon, as well as at noon (Fig. 1). Its level is about 6.10^{-3} cm O_3 above the single curve for October 2nd. If this systematic displacement is taken into

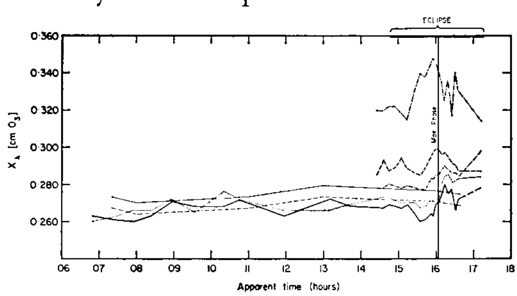

Fig. 1. Variation of ozone amount.

Means of 8 days

Means of 8 days diminished by $6 \cdot 10^{-3}$ (cm O_3)

X_{AC}

X_{AD}

X_A

X_C

X_D

account, the following deviations of ozone amount against its daily mean value are found for $\lambda\lambda AD$ and AC during the period of eclipse. (Table 1.)

Table 1

Apparent time	$x_{\lambda\lambda}-\overline{x_{\lambda\lambda}}$		
14.54	-1.10^{-3} cm O_3	1st contact	
15.04	-2		
15.13	-1		
15.24	-4		ci
15.34	-7		ci
15.42	-6		ci
15.52	-2		ci
15.55	-3		ci
15.59	$+1$		ci
16.03	$+1$	max.phase	ci
16.08	$+8$		ci
16.13	$+12$		ci
16.18	$+10$		ci
16.25	$+10$		ci
16.30	$+5$		ci
16.35	$+9$		ci
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17.11 measurement unreliable because of low sun and clouds.			

The greatest positive deviation about 10 minutes after the maximum phase is $\Delta x = +12.10^{-3}$ cm O_3, almost reaching 3σ. It can be regarded as significant and a possible explanation may be the diminution of ultraviolet radiation J_3 responsible for the disintegration of ozone. The formation of ozone by triple collision will still go on during the eclipse, since the quantity of oxygen atoms will certainly not change considerably. The ratio of energies absorbed by O_3 and O_2 will have decreased (1).

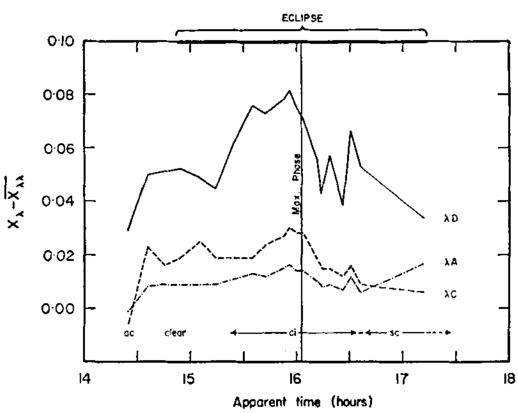

Fig. 2. Turbidity effect on ozone results.

The surplus of ozone during the second half of the eclipse of about 4 % of the total against its mean value may thus represent a real increase due to the disturbed conditions of photochemical equilibrium in that part of the layer where the time of returning to equilibrium state is of the order of 10—20 minutes, i.e., in the very high level well above the maximum of ozone concentration. A change of 4 % of total ozone means, however, quite a considerable portion of this uppermost region of the ozone layer involved in the disturbance. The stabilizing effect of increased heating will soon reduce the ozone concentration to its earlier level.

The ozone values expressed in x_λ of one wavelength pair only ($\lambda = A$ and C) show a similar behaviour as those obtained from the differences of measurements of two wavelength pairs ($\lambda\lambda = AD$ and AC) (Fig. 1). The increase begins about 20 minutes before the maximum phase of the eclipse. The variation is most pronounced on λA, the random variations always being greater on λC. No evident minimum is found on λA in the first phase of the eclipse. It can be assumed that the minimum found for x_{AD} is due to the increase of the λD values starting already 25 minutes after the first contact, which must be attributed to the appearance of thin cirrus clouds. It is known that λD is rather sensitive to atmospheric turbidity, the ratio of dust effect to ozone effect being greatest for this wavelength pair (Fig. 2). A non significant dip is thus only found for x_{AC} which begins to rise as x_A and x_C at 15.40 hours. If one reduces the peak of x_D between 15.24 and 16.05 hours the variation of x_{AD} would be similar to that of x_{AC}.

The series of ozone values on October 2nd are as seen in Table 2.

In figure 3 we now see the various results of ozone observations during solar eclipses which have been published earlier. The uppermost curve gives the results from an eclipse in Russia in 1952 (BEZVERKHNII ET AL.). These measurements have been carried out with an electrophotometer and silver filters, probably of interferential type. A considerable rise of ozone values is recorded, starting shortly before maximum phase. The minimum still earlier has not been explained by the authors, they supposed it to be due to meteorological effects. Underneath are represented two of

Table 2

Apparent time	Type	μ	x_{AC}	x_{AD}	Mean x	x_A	x_C	x_D	$x_A - \overline{x}_{\lambda\lambda}$	$x_C - \overline{x}_{\lambda\lambda}$	$x_D - \overline{x}_{\lambda\lambda}$
06.49	ZC	4.44	0.260	0.263	0.262						
07.21	ZC	2.84	0.262	0.261	0.262						
07.56	ZC	2.05	0.266	0.260	0.263						
08.24	ZC	1.69	0.266	0.263	0.265						
08.58	ZC	1.42	0.272	0.271	0.272						
09.35	ZC	1.24	0.265	0.268	0.267						
10.20	ZC	1.11	0.276	0.268	0.272						
10.46	ZC	1.06	0.272	0.272	0.272						
11.57	ZC	1.00	0.266	0.263	0.265						
13.10	ZC	1.05	0.266	0.272	0.269						
13.37	ZC	1.10	0.269	0.269	0.269						
13.41	ZC	1.11	0 269	0.268	0.269						
14.25[1]	(SF)	1.24	(0.298)	(0.283)	(0.291)	(0.290)	(0.285)	(0.320)	(−0.001)	(−0.006)	(0.029)
14.36	SF	1.29	0.273	0.267	0.270	0.278	0.293	0.320	0.008	0.023	0.050
14.45	SF	1.33	0.273	0.269	0.271	0.280	0.287	0.322	0.009	0.016	0.051
14.55	SF	1.39	0.271	0.268	0.270	0.279	0.289	0.322	0.009	0.019	0.052
15.05	SF	1.45	0.270	0.267	0.269	0.278	0.294	0.318	0.009	0.025	0.049
15.14	SF	1.51	0.270	0.269	0.270	0.279	0.289	0.315	0.009	0.019	0.045
15.25	SF	1.60	0.270	0.264	0.267	0.278	0.286	0.329	0.011	0.019	0.062
15.35	SF	1.69	0.267	0.260	0.264	0.277	0.285	0.340	0.013	0.019	0.076
15.43	SF	1.77	0.268	0.261	0.265	0.277	0.289	0.338	0.012	0.024	0.073
15.53	SF	1.90	0.272	0.264	0.268	0.283	0.295	0.346	0.015	0.027	0.078
15.56	SF	1.93	0.271	0.263	0.267	0.283	0.297	0.348	0.016	0.030	0.081
16.00	SF	1.99	0.272	0.269	0.271	0.285	0.299	0.346	0.014	0.028	0.075
16.04	SF	2.05	0.272	0.270	0.271	0.285	0.299	0.341	0.014	0.028	0.070
16.09	SF	2.13	0.281	0.275	0.278	0.288	0.296	0.334	0.010	0.018	0.056
16.14	SF	2.22	0.284	0.280	0.282	0.290	0.297	0.325	0.008	0.015	0.043
16.19	SF	2.32	0.283	0.275	0.279	0.288	0.294	0.336	0.009	0.015	0.057
16.26	SF	2.48	0.281	0.277	0.279	0.286	0.291	0.318	0.007	0.012	0.039
16.31	SF	2.60	0.282	0.266	0.274	0.286	0.290	0.340	0.012	0.016	0.066
16.36	SF	2.74	0.283	0.272	0.278	0.284	0.287	0.331	0.006	0.009	0.053
17.09	ZB	4.30	(0.241	0.256)	(0.249)	—	—	—	—	—	—
17.12[1]	(SF)	4.52	(0.284)	(0.278)	(0.281)	(0.298)	0.287	0.315	(0.017)	0.006	0.034

[1] Cloudy.

Svensson's curves after correction for the limb-darkening effect on L_0 of June 1954 in Sweden (Svensson, 1958). There is scarcely any deviation of x for the difference of wavelength pairs A and D during the eclipse, whilst there is a slight surplus of ozone against the mean trend for λA after the maximum phase of the eclipse. As nothing is mentioned in Svensson's paper about the kind of observations, it must be assumed that the usual routine measurements of Dobson spectrophotometer with the ground quartz plate were made, thus amplifying the effect of L_0 change in the course of the eclipse. This effect symmetric to the maximum phase is evident from his uncorrected curves, (his figures 8a—c). Next comes the eclipse observations on the same day as achieved by Fournier d'Albe and Rasool (1956) in Pakistan. Here the sun was already very low, so that they could only use the D-wavelength pair which prevented any significant deviation of O_3 to be obtained. Finally three of the representative curves (λAC; λAD and λA) of the Congo observations in 1959 are repeated for comparison. These measurements were made with the focussed image of the sun which gave approximately the same shape of the curves as those drawn by Svensson after correcting for the limb-darkening effect.

Jerlov, Olsson and Schüepp (1954) have also published the results of their observations obtained in the Chappuis bands. They believe to have found a decrease of ozone during the eclipse in 1945, but a private communication by Dr. Schüepp later says that the decrease cannot be regarded as well established and

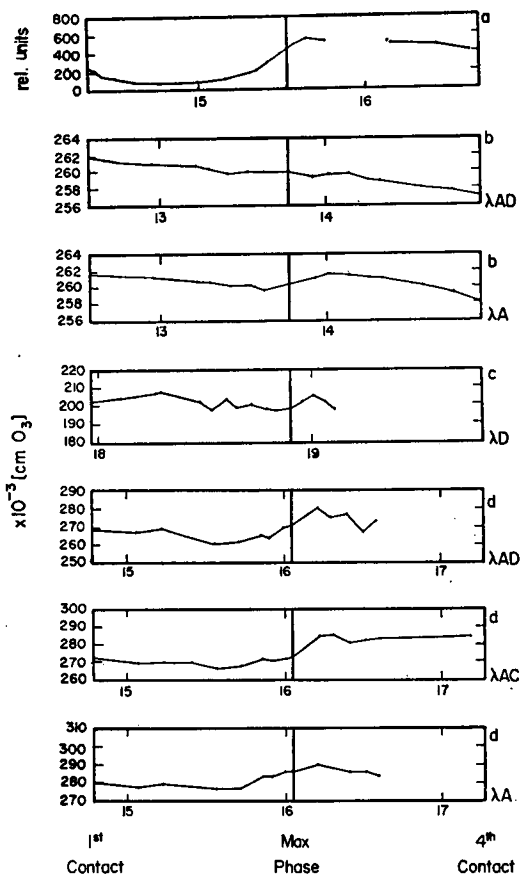

Fig. 3. Ozone observations during solar eclipses.

a: Russia 25.2.1952, $h_{\odot}=25°$, 100 % eclipse.

b: Sweden 30.6.1954, $h_{\odot}=48°$, 95 % eclipse (corrected for limb darkening).

c: Pakistan 30.6.1954, $h_{\odot}=9°$, 100 % eclipse.

d: Congo 2.10.1959, $h_{\odot}=30°$, 80 % eclipse.

might rather have been due to other atmospheric effects, may be haze.

It remains still questionable whether the corrections by Svensson to eliminate the remaining slight increase of ozone after phase maximum which he tends to attribute to atmospheric effects, are justified or not. Because the effect of cirrus on x_D observed in Bunia is evidently a different one occurring on λ_D already before the maximum phase, than that showing the increase, particularly on λA, shortly after the maximum phase. It could well prove justified that somewhat more weight ought to be put to this maximum which appears in several of the ozone observations during solar eclipses independent of the type and kind of measurement or instrument. It should, of course, be most pronounced where the total ozone is least, and where there is little or no ozone in the lower part of the ozone region underneath it's maximum concentration, i.e., in low latitudes.

Summary

Ozone measurements with the Dobson spectrophotometer on direct sunlight during the solar eclipse of October 2nd, 1959, show a rise of total ozone by about 4 % above the mean level before the eclipse. The increase begins about 45 minutes after the first contact of the moon, or 20 minutes before the maximum phase when 80 % of the sun's disk were covered by the moon. This higher level of total ozone appears to have persisted with a slight decrease during the second half of the eclipse. The return to the original level could unfortunately not be followed because of clouds and the approach to sunset.

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