II—THE CALCULATION OF THE VERTICAL DISTRIBUTION OF OZONE BY THE GÖTZ UMKEHR-EFFECT (METHOD B)

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1 Introduction

The present note gives the details of Method B for calculating the vertical distribution of ozone in the atmosphere from observations on the umkehr-effect. The method was originally due to Götz, Meetham, and Dobson (1934).

Although the method is not free from objection, it gives information of value about the changes in the vertical distribution of ozone associated with day-to-day changes in weather; it is also comparatively easy to use in clear weather at all stations equipped with a Dobson Spectrophotometer.

The measurements required are the ratios of the intensities of light of two wave-lengths from the clear zenith sky, one of which is much more absorbed by ozone than the other, for zenith distances Z of the sun varying from 40° or 60° to 90°. Considering, for example, the light of two wave-lengths 3112 Å and 3323 Å (for which the decimal absorption coefficients of ozone are 1·23 and 0·08 respectively), it is found that the ratio $L = \log [I_{(3112)}/I_{(3323)}]$ in the light from the zenith sky decreases as Z increases until a value of about 86·5° is reached, and then increases as Z increases to 90°.

Instead of L, one can plot $N = 100(L_0 - L)$ where L_0 is the value of L extrapolated for a point outside the atmosphere. It is the general practice to plot L or N against Z^4 so as to give an open scale when the sun is near the horizon.

Sample curves of N against Z^4 for λλ 3112/3323 and λλ 3054/3253 are shown in Fig. 1. (Curves C and A respectively.)

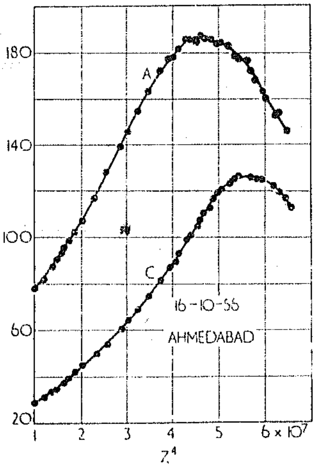

Fig. 1. Umkehr curves with Dobson Spectrophotometer.

Annals of the IGY, Pergamon Press, London, 5, 23-45, 1957.

The light reaching the observer from the sky in any direction is sunlight scattered by the whole column of atmosphere in that direction. It includes primary as well as multiply scattered light. If only primary scattered light from molecules is considered, it is easy to obtain an expression for the light of any wave-length reaching the observer from the zenith.

In Section 2, the method of calculating the vertical distribution of ozone is described, first on the assumption that the light from the zenith sky is solely primary scattered light. A short section is added explaining the effect of secondary scattered light and a method of correcting for it. A fully worked out example follows.

In Section 3, supplementary tables applicable to stations at or near two higher levels, 912 mb and 810 mb, are provided.

2 Calculation of Primary Scattered Light received from the Zenith Sky at the Ground

For calculating the light scattered vertically downward, the atmosphere is divided into layers (Karandikar and Ramanathan, 1949). The first layer is from the ground (1013 mb/level) to 6 km. The second level is from 6 km to 12 km. The other layers are each 6 km thick up to 54 km, and above 54 km the whole atmosphere is treated as one layer.

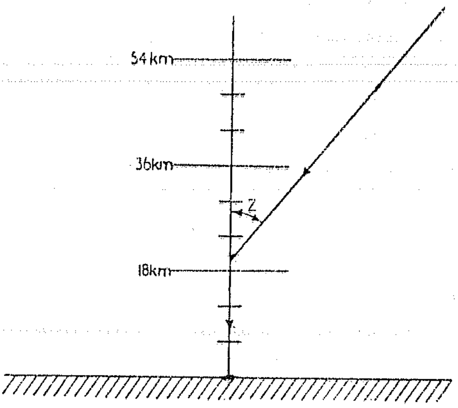

Fig. 2. Division of the atmosphere into 6 km. layers.

p_0	1013 mb.
p	Pressure at height h taken from rocket panel data. (Table 1.)
Δm_n	Mass of air in the nth layer, expressed as a fraction of the total mass of air in a standard atmosphere which exerts a pressure of 1013 mb at its base. The air in each 6 km layer is supposed to be concentrated at a height of 2 km above the base of the layer. These assumptions are not free from objection, but are simple and reasonably accurate.
α, α'	Decimal absorption coefficients of ozone for λ, λ' (per cm of ozone at S.T.P.) (Table 3). The table includes data for all the four pairs of wave-lengths normally used for ozone determination with the Ozone Spectrophotometer.

β, β' Decimal scattering coefficients for light of wave-lengths λ, λ' by a standard atmosphere (Table 3).

F_h Integrated air-path from the top of the atmosphere to h (expressed as multiple of air-mass in one standard atmosphere), and from h vertically downward to the observer. (Table 4.) For an observer at pressure-level $p_0 = 1013$ mb, $F_h = 1+(p/p_0)[\mathrm{Ch}(Z)-1]$ where Ch(Z) is the Chapman Function for a spherical atmosphere for zenith angle Z with the vertical through the observer. The values of Ch(Z) have been tabulated by M. V. WILKES (1954). While considering air-mass in the slant path above a particular height h, it is to be noted that the temperature of the air in the first few kilometres above h exerts a dominant influence. The mean temperatures in the atmosphere as shown by rocket ascents have been taken as a guide in preparing Table 1A of the values of Ch(Z).

If the observer is located at a pressure-level kp_0 instead of at p_0, the values of F_h in all rows in Table 4 except the first row (corresponding to 2 km) should be changed to $k+p/p_0[\mathrm{Ch}(Z)-1]$. Supplementary Table 4X has been prepared for $k = 0{\cdot}9$ and $0{\cdot}8$ corresponding to pressure levels 912 and 810 mb respectively. These will hold for stations at 1 km and 2 km respectively above sea level. For the lowest layer, in Table 4X, h has been taken to be 3 km above 1013-mb level. This is sufficiently accurate.

Δs Total geometrical slant path of light in each layer.

Δh Corresponding vertical path in the layer.

$\Delta s - \Delta h$ have been tabulated in Table 6 for all those layers in which there is a slant path. A constant value of the radius of the earth $a = 6370$ km has been used. See Fig. 3. For layers in which there is only a vertical path $\Delta s - \Delta h = 0$.

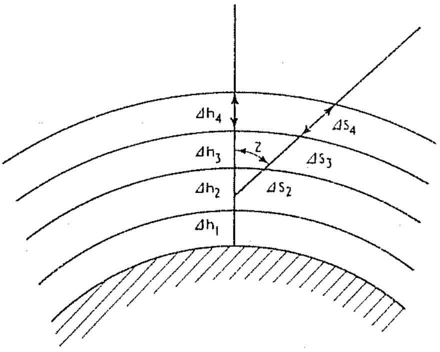

Fig. 3. Diagram explaining Δs and Δh.

y_1, y_2, y_3, etc. up to y_9 are the ozone amounts in 10^{-3} cm/km in successive layers as we go up; it is assumed that the ozone amount above 54 km is negligible so that the total ozone amount $x = 6y_1+6(y_2+ \dots +y_9)$. The factor 6 in the first term on the right will require a small adjustment if the station is above the 1013-mb level.

The total ozone Y in the path of the light, when the zenith distance of the sun is Z and the light is scattered from the nth layer, is given by the sum of the ozone

Table 1. Pressure at different heights above sea-leve
(From rocket panel data)

Height km	Pressure mb	Height km	Pressure mb
0	1013	44	1·90
2	803·5	48	1·15
6	487·5	50	0·902
8	372·4	54	0·547
12	206·5	56	0·426
14	150·7	60	0·254
18	78·5	62	0·194
20	56·9	66	0·111
24	30·5	68	0·082
26	22·5	72	0·045
30	12·5	74	0·033
32	9·31	78	0·017
36	5·32	80	0·012
38	4·07	84	0·007
42	2·43		

Table 1A. Values of Ch(Z) adopted for different values of h(km) and of Z(degrees). The rocket temperatures at h to $h+10$(km) have been taken into consideration in tabulating these values.

h (km) \ Z	37°	60°	70°	75°	80°	84°	86·5°	88°	90°
2, 3	1·251	1·993	2·90	3·80	5·55	8·73	13·3	18·7	35·5
8	1·251	1·993	2·90	3·81	5·58	8·84	13·6	19·5	38·7
14, 20	1·251	1·993	2·90	3·81	5·59	8·87	13·7	19·7	39·7
26, 32	1·251	1·993	2·90	3·81	5·57	8·81	13·5	19·2	37·6
38, 44, 50	1·251	1·993	2·90	3·80	5·55	8·73	13·3	18·7	35·5
56	1·251	1·993	2·90	3·80	5·56	8·77	13·4	19·0	36·6
62	1·251	1·993	2·90	3·81	5·57	8·81	13·5	19·2	37·6
68	1·251	1·993	2·90	3·81	5·59	8·87	13·7	19·7	39·7

Table 2. Logarithm of the mass of air in different layers expressed as fraction of the mass in a vertical column of the standard atmosphere

Layer	Log Δm_n	Layer	Log Δm_n
0–6	$\bar{1}$·715	42–48	$\bar{3}$·100
6–12	$\bar{1}$·443	48–54	$\bar{4}$·778
12–18	$\bar{1}$·101	54–60	$\bar{4}$·461
18–24	$\bar{2}$·676	60–66	$\bar{4}$·149
24–30	$\bar{2}$·250	66–72	$\bar{5}$·820
30–36	$\bar{3}$·848	72–78	$\bar{5}$·431
36–42	$\bar{3}$·455	78–84	$\bar{5}$·000

Table 3. Decimal absorption coefficients of ozone and scattering coefficients of atmosphere for light of different pairs of wave-lengths

	λ/λ'	α	α'	β	β'	Log (β/β')
A	3054/3253	2·58	0·16	0·503	0·384	0·1173
B	3085/3291	1·77	0·12	0·481	0·365	0·1198
C	3112/3323	1·23	0·08	0·464	0·350	0·1224
D	3175/3399	0·54	0·02	0·425	0·318	0·1260

α, α' refer to 1 cm of ozone at S.T.P. and β, β' to an atmosphere which exerts a pressure of 1013 mb at its base.

Note.—After all calculations were completed, it was seen that the values of β and β' as given here and as used for all the other tables are about 2% too high, because the depolarization correction for molecular anistrophy has been taken to be $6(1+\rho)/(6-7\rho)$. This should have been $(6+3\rho)/(6-7\rho)$.

Table 4. Values of F_h—Integrated air path (expressed as multiple of one standard atmosphere) from the top of the atmosphere to the level of primary scattering and from that level to the observer at $p_0 = 1013$ mb

Z / h	37°	60°	70°	75°	80°	84°	86·5°	88°	90°
2	1·199	1·788	2·505	3·221	4·610	7·133	10·748	15·032	28·342
8	1·092	1·365	1·699	2·033	2·684	3·882	5·635	7·786	14·859
14	1·037	1·148	1·283	1·418	1·683	2·171	2·887	3·778	6·751
20	1·014	1·056	1·107	1·158	1·258	1·441	1·713	2·049	3·172
26	1·006	1·022	1·042	1·062	1·101	1·173	1·278	1·404	1·813
32	1·002	1·009	1·017	1·026	1·042	1·072	1·115	1·167	1·337
38	1·001	1·004	1·008	1·011	1·018	1·031	1·049	1·071	1·139
44	1·000	1·002	1·004	1·005	1·009	1·015	1·023	1·033	1·065
50	1·000	1·001	1·002	1·002	1·004	1·007	1·011	1·016	1·031
56	1·000	1·000	1·001	1·001	1·002	1·003	1·005	1·008	1·015
62	1·000	1·000	1·000	1·001	1·001	1·001	1·002	1·003	1·007
68	1·000	1·000	1·000	1·000	1·000	1·001	1·001	1·001	1·003
74	1·000	1·000	1·000	1·000	1·000	1·000	1·000	1·001	1·001
80	1·000	1·000	1·000	1·000	1·000	1·000	1·000	1·000	1·000

$$F_h = 1+(p/p_0)[\mathrm{Ch}(Z)-1)$$

amounts in the slant path and in the vertical path. In the nth and higher layers, part of the path is vertical and part slant.

$$\begin{aligned} Y &= \sum_{n}^{9} y_r \Delta s_r + \sum_{1}^{n} y_r \Delta h_r \\ &= \sum_{n}^{9} y_r(\Delta s_r - \Delta h_r) + \sum_{1}^{9} y_r \Delta h_r \\ &= Y_n + x. \end{aligned}$$

Tables 6 provide the values of $\Delta s - \Delta h$ for calculating Y_n for the light scattered from each layer and for different zenith distances of the sun ranging from 37° to 90°. An example of the calculation of Y is given in Table 8.

The intensities of the primary scattered light of wave-length λ for the nth layer at the ground is given by $\Delta I_n = K.\ \beta\ .\ \Delta m_n \times 10^{-\beta F - \alpha Y}$ where K is a constant depending on the value of Z, and I the total intensity from all the layers is given by

$$I = \Sigma\, \Delta I_n = K.\beta[\sum_1^{10} \Delta m_n \times 10^{-\beta F - \alpha Y}].$$

The ratio of the intensities of the primary scattered light of two wave-lengths λ and λ' from the zenith sky is given by

$$\frac{I}{I'} = \frac{\beta}{\beta'} \frac{\sum_1^{10} [\Delta m_n \times 10^{-\beta F - \alpha Y}]}{\sum_1^{10} [\Delta m_n \times 10^{-\beta' F - \alpha' Y}]}$$

The values of $\log \Delta m_n - \beta F$ for different layers and different values of Z required in the computation of $\log(I'/I)$ are given in Tables 5A, B, C, and D, corresponding to different pairs of wave-lengths.

Forms I, II and III are for computing $\log(I'/I)$ for any assumed ozone distribution and for making changes in it corresponding to small changes in the distribution. These are given at the end of Section 3.

By the method of successive approximation, the ozone amounts in the different layers are so adjusted that the calculated values of $\log(I'/I)$ agree with the calculated values at four or five points of the umkehr curve within the limits of experimental error. In practice, a constant is added to the calculated value of $\log(I'/I)$ so that the calculated and the observed values coincide at some fixed zenith distance such as 60°, where the intensity is determined mainly by the *total* amount of ozone

Table 5A

$\text{Log } \Delta m_n - \beta F$ $\beta(3054) = 0{\cdot}503$

n Z	1	2	3	4	5	6	7	8	9	10
37°	$\bar{1}{\cdot}112$	$\bar{2}{\cdot}894$	$\bar{2}{\cdot}579$	$\bar{2}{\cdot}166$	$\bar{3}{\cdot}744$	$\bar{3}{\cdot}344$	$\bar{4}{\cdot}951$	$\bar{4}{\cdot}597$	$\bar{4}{\cdot}275$	$\bar{4}{\cdot}228$
60	$\bar{2}{\cdot}816$	$\bar{2}{\cdot}756$	$\bar{2}{\cdot}524$	$\bar{2}{\cdot}145$	$\bar{3}{\cdot}736$	$\bar{3}{\cdot}340$	$\bar{4}{\cdot}950$	$\bar{4}{\cdot}596$	$\bar{4}{\cdot}274$	$\bar{4}{\cdot}228$
70	$\bar{2}{\cdot}455$	$\bar{2}{\cdot}588$	$\bar{2}{\cdot}456$	$\bar{2}{\cdot}119$	$\bar{3}{\cdot}726$	$\bar{3}{\cdot}336$	$\bar{4}{\cdot}948$	$\bar{4}{\cdot}595$	$\bar{4}{\cdot}274$	$\bar{4}{\cdot}228$
75	$\bar{2}{\cdot}095$	$\bar{2}{\cdot}420$	$\bar{2}{\cdot}388$	$\bar{2}{\cdot}094$	$\bar{3}{\cdot}716$	$\bar{3}{\cdot}332$	$\bar{4}{\cdot}946$	$\bar{4}{\cdot}594$	$\bar{4}{\cdot}274$	$\bar{4}{\cdot}228$
80	$\bar{3}{\cdot}396$	$\bar{2}{\cdot}093$	$\bar{2}{\cdot}254$	$\bar{2}{\cdot}043$	$\bar{3}{\cdot}696$	$\bar{3}{\cdot}324$	$\bar{4}{\cdot}943$	$\bar{4}{\cdot}592$	$\bar{4}{\cdot}273$	$\bar{4}{\cdot}228$
84	$\bar{4}{\cdot}127$	$\bar{3}{\cdot}490$	$\bar{2}{\cdot}009$	$\bar{3}{\cdot}951$	$\bar{3}{\cdot}660$	$\bar{3}{\cdot}309$	$\bar{4}{\cdot}936$	$\bar{4}{\cdot}589$	$\bar{4}{\cdot}271$	$\bar{4}{\cdot}225$
86·5	$\bar{6}{\cdot}309$	$\bar{4}{\cdot}609$	$\bar{3}{\cdot}649$	$\bar{3}{\cdot}814$	$\bar{3}{\cdot}607$	$\bar{3}{\cdot}287$	$\bar{4}{\cdot}927$	$\bar{4}{\cdot}585$	$\bar{4}{\cdot}269$	$\bar{4}{\cdot}225$
88	$\bar{8}{\cdot}154$	$\bar{5}{\cdot}527$	$\bar{3}{\cdot}201$	$\bar{3}{\cdot}645$	$\bar{3}{\cdot}544$	$\bar{3}{\cdot}261$	$\bar{4}{\cdot}916$	$\bar{4}{\cdot}580$	$\bar{4}{\cdot}267$	$\bar{4}{\cdot}225$
90	$\overline{15}{\cdot}459$	$\bar{9}{\cdot}969$	$\bar{5}{\cdot}705$	$\bar{3}{\cdot}080$	$\bar{3}{\cdot}338$	$\bar{3}{\cdot}175$	$\bar{4}{\cdot}882$	$\bar{4}{\cdot}564$	$\bar{4}{\cdot}259$	$\bar{4}{\cdot}223$

Table 5A (contd.)

Log $\Delta m_n - \beta' F$ $\beta'(3253) = 0{\cdot}384$

Z \ n	1	2	3	4	5	6	7	8	9	10
37°	$\bar{1}$·255	$\bar{1}$·024	$\bar{2}$·703	$\bar{2}$·287	$\bar{3}$·864	$\bar{3}$·463	$\bar{3}$·071	$\bar{4}$·716	$\bar{4}$·394	$\bar{4}$·346
60	$\bar{1}$·028	$\bar{2}$·919	$\bar{2}$·660	$\bar{2}$·270	$\bar{3}$·858	$\bar{3}$·461	$\bar{3}$·069	$\bar{4}$·715	$\bar{4}$·394	$\bar{4}$·346
70	$\bar{2}$·753	$\bar{2}$·791	$\bar{2}$·608	$\bar{2}$·251	$\bar{3}$·850	$\bar{3}$·457	$\bar{3}$·068	$\bar{4}$·714	$\bar{4}$·393	$\bar{4}$·346
75	$\bar{2}$·478	$\bar{2}$·662	$\bar{2}$·556	$\bar{2}$·231	$\bar{3}$·842	$\bar{3}$·454	$\bar{3}$·067	$\bar{4}$·714	$\bar{4}$·393	$\bar{4}$·346
80	$\bar{3}$·945	$\bar{2}$·412	$\bar{2}$·455	$\bar{2}$·193	$\bar{3}$·827	$\bar{3}$·448	$\bar{3}$·064	$\bar{4}$·713	$\bar{4}$·392	$\bar{4}$·346
84	$\bar{4}$·976	$\bar{3}$·952	$\bar{2}$·267	$\bar{2}$·123	$\bar{3}$·800	$\bar{3}$·436	$\bar{3}$·059	$\bar{4}$·710	$\bar{4}$·391	$\bar{4}$·346
86·5	$\bar{5}$·588	$\bar{3}$·279	$\bar{3}$·992	$\bar{2}$·018	$\bar{3}$·759	$\bar{3}$·420	$\bar{3}$·052	$\bar{4}$·707	$\bar{4}$·390	$\bar{4}$·346
88	$\bar{7}$·943	$\bar{4}$·453	$\bar{3}$·650	$\bar{3}$·889	$\bar{3}$·711	$\bar{3}$·400	$\bar{3}$·044	$\bar{4}$·703	$\bar{4}$·388	$\bar{4}$·346
90	$\overline{12}$·832	$\bar{7}$·737	$\bar{4}$·509	$\bar{3}$·458	$\bar{3}$·554	$\bar{3}$·335	$\bar{3}$·018	$\bar{4}$·691	$\bar{4}$·382	$\bar{4}$·344

Table 5B

Log $\Delta m_n - \beta F$ $\beta(3085) = 0{\cdot}481$

Z \ n	1	2	3	4	5	6	7	8	9	10
37°	$\bar{1}$·138	$\bar{2}$·918	$\bar{2}$·602	$\bar{2}$·188	$\bar{3}$·766	$\bar{3}$·366	$\bar{4}$·974	$\bar{4}$·619	$\bar{4}$·297	$\bar{4}$·255
60	$\bar{2}$·855	$\bar{2}$·786	$\bar{2}$·549	$\bar{2}$·168	$\bar{3}$·758	$\bar{3}$·363	$\bar{4}$·972	$\bar{4}$·618	$\bar{4}$·297	$\bar{4}$·255
70	$\bar{2}$·510	$\bar{2}$·626	$\bar{2}$·484	$\bar{2}$·144	$\bar{3}$·749	$\bar{3}$·359	$\bar{4}$·970	$\bar{4}$·617	$\bar{4}$·296	$\bar{4}$·255
75	$\bar{2}$·166	$\bar{2}$·465	$\bar{2}$·419	$\bar{2}$·119	$\bar{3}$·739	$\bar{3}$·354	$\bar{4}$·969	$\bar{4}$·617	$\bar{4}$·296	$\bar{4}$·255
80	$\bar{3}$·498	$\bar{2}$·152	$\bar{2}$·291	$\bar{2}$·071	$\bar{3}$·720	$\bar{3}$·347	$\bar{4}$·965	$\bar{4}$·615	$\bar{4}$·295	$\bar{4}$·253
84	$\bar{4}$·284	$\bar{3}$·576	$\bar{2}$·057	$\bar{3}$·983	$\bar{3}$·686	$\bar{3}$·332	$\bar{4}$·959	$\bar{4}$·612	$\bar{4}$·294	$\bar{4}$·253
86·5	$\bar{6}$·545	$\bar{4}$·733	$\bar{3}$·712	$\bar{3}$·852	$\bar{3}$·635	$\bar{3}$·312	$\bar{4}$·950	$\bar{4}$·608	$\bar{4}$·292	$\bar{4}$·250
88	$\bar{8}$·485	$\bar{5}$·698	$\bar{3}$·284	$\bar{3}$·690	$\bar{3}$·575	$\bar{3}$·287	$\bar{4}$·940	$\bar{4}$·603	$\bar{4}$·289	$\bar{4}$·250
90	$\overline{14}$·082	$\bar{8}$·296	$\bar{5}$·854	$\bar{3}$·150	$\bar{3}$·378	$\bar{3}$·205	$\bar{4}$·907	$\bar{4}$·588	$\bar{4}$·282	$\bar{4}$·248

Table 5B (contd.)

Log $\Delta m_n - \beta' F$ $\beta'(3291) = 0{\cdot}365$

Z \ n	1	2	3	4	5	6	7	8	9	10
37°	$\bar{1}$·277	$\bar{1}$·044	$\bar{2}$·722	$\bar{2}$·306	$\bar{3}$·883	$\bar{3}$·482	$\bar{3}$·090	$\bar{4}$·735	$\bar{4}$·413	$\bar{4}$·369
60	$\bar{1}$·062	$\bar{2}$·945	$\bar{2}$·682	$\bar{2}$·291	$\bar{3}$·877	$\bar{3}$·480	$\bar{3}$·089	$\bar{4}$·734	$\bar{4}$·413	$\bar{4}$·369
70	$\bar{2}$·801	$\bar{2}$·823	$\bar{2}$·633	$\bar{2}$·272	$\bar{3}$·870	$\bar{3}$·477	$\bar{3}$·087	$\bar{4}$·734	$\bar{4}$·412	$\bar{4}$·369
75	$\bar{2}$·539	$\bar{2}$·701	$\bar{2}$·583	$\bar{2}$·253	$\bar{3}$·862	$\bar{3}$·474	$\bar{3}$·086	$\bar{4}$·733	$\bar{4}$·412	$\bar{4}$·369
80	$\bar{2}$·032	$\bar{2}$·463	$\bar{2}$·487	$\bar{2}$·217	$\bar{3}$·848	$\bar{3}$·468	$\bar{3}$·083	$\bar{4}$·732	$\bar{4}$·412	$\bar{4}$·369
84	$\bar{3}$·111	$\bar{2}$·026	$\bar{2}$·309	$\bar{2}$·150	$\bar{3}$·822	$\bar{3}$·457	$\bar{3}$·079	$\bar{4}$·730	$\bar{4}$·410	$\bar{4}$·369
86·5	$\bar{5}$·792	$\bar{3}$·386	$\bar{2}$·047	$\bar{2}$·051	$\bar{3}$·784	$\bar{3}$·441	$\bar{3}$·072	$\bar{4}$·727	$\bar{4}$·409	$\bar{4}$·367
88	$\bar{6}$·228	$\bar{4}$·601	$\bar{3}$·722	$\bar{3}$·928	$\bar{3}$·738	$\bar{3}$·422	$\bar{3}$·064	$\bar{4}$·723	$\bar{4}$·407	$\bar{4}$·367
90	$\overline{11}$·370	$\bar{6}$·019	$\bar{4}$·637	$\bar{3}$·518	$\bar{3}$·588	$\bar{3}$·360	$\bar{3}$·039	$\bar{4}$·711	$\bar{4}$·402	$\bar{4}$·362

Table 5C

Log $\Delta m_n - \beta F$ $\beta(3112) = 0{\cdot}464$

Z \ n	1	2	3	4	5	6	7	8	9	10
37°	$\bar{1}\cdot159$	$\bar{2}\cdot936$	$\bar{2}\cdot620$	$\bar{2}\cdot206$	$\bar{3}\cdot783$	$\bar{3}\cdot383$	$\bar{4}\cdot991$	$\bar{4}\cdot636$	$\bar{4}\cdot314$	$\bar{4}\cdot267$
60	$\bar{2}\cdot885$	$\bar{2}\cdot810$	$\bar{2}\cdot568$	$\bar{2}\cdot186$	$\bar{3}\cdot776$	$\bar{3}\cdot380$	$\bar{4}\cdot989$	$\bar{4}\cdot635$	$\bar{4}\cdot314$	$\bar{4}\cdot267$
70	$\bar{2}\cdot553$	$\bar{2}\cdot655$	$\bar{2}\cdot506$	$\bar{2}\cdot162$	$\bar{3}\cdot767$	$\bar{3}\cdot376$	$\bar{4}\cdot987$	$\bar{4}\cdot634$	$\bar{4}\cdot313$	$\bar{4}\cdot267$
75	$\bar{2}\cdot220$	$\bar{2}\cdot500$	$\bar{2}\cdot443$	$\bar{2}\cdot139$	$\bar{3}\cdot757$	$\bar{3}\cdot372$	$\bar{4}\cdot986$	$\bar{4}\cdot634$	$\bar{4}\cdot313$	$\bar{4}\cdot267$
80	$\bar{3}\cdot576$	$\bar{2}\cdot198$	$\bar{2}\cdot320$	$\bar{2}\cdot092$	$\bar{3}\cdot739$	$\bar{3}\cdot365$	$\bar{4}\cdot983$	$\bar{4}\cdot632$	$\bar{4}\cdot312$	$\bar{4}\cdot267$
84	$\bar{4}\cdot405$	$\bar{3}\cdot642$	$\bar{2}\cdot094$	$\bar{2}\cdot007$	$\bar{3}\cdot706$	$\bar{3}\cdot351$	$\bar{4}\cdot977$	$\bar{4}\cdot629$	$\bar{4}\cdot311$	$\bar{4}\cdot267$
86·5	$\bar{6}\cdot728$	$\bar{4}\cdot828$	$\bar{3}\cdot761$	$\bar{3}\cdot881$	$\bar{3}\cdot657$	$\bar{3}\cdot331$	$\bar{4}\cdot968$	$\bar{4}\cdot625$	$\bar{4}\cdot309$	$\bar{4}\cdot267$
88	$\bar{8}\cdot740$	$\bar{5}\cdot830$	$\bar{3}\cdot348$	$\bar{3}\cdot725$	$\bar{3}\cdot599$	$\bar{3}\cdot307$	$\bar{4}\cdot958$	$\bar{4}\cdot621$	$\bar{4}\cdot307$	$\bar{4}\cdot265$
90	$\overline{14}\cdot564$	$\bar{8}\cdot548$	$\bar{5}\cdot969$	$\bar{3}\cdot204$	$\bar{3}\cdot409$	$\bar{3}\cdot228$	$\bar{4}\cdot927$	$\bar{4}\cdot606$	$\bar{4}\cdot300$	$\bar{4}\cdot265$

Table 5C (contd.)

C

Log $\Delta m_n - \beta' F$ $\beta'(3323) = 0{\cdot}350$

Z \ n	1	2	3	4	5	6	7	8	9	10
37°	$\bar{1}\cdot295$	$\bar{1}\cdot061$	$\bar{2}\cdot738$	$\bar{2}\cdot321$	$\bar{3}\cdot898$	$\bar{3}\cdot497$	$\bar{3}\cdot105$	$\bar{4}\cdot750$	$\bar{4}\cdot428$	$\bar{4}\cdot382$
60	$\bar{1}\cdot089$	$\bar{2}\cdot965$	$\bar{2}\cdot699$	$\bar{2}\cdot306$	$\bar{3}\cdot892$	$\bar{3}\cdot495$	$\bar{3}\cdot104$	$\bar{4}\cdot749$	$\bar{4}\cdot428$	$\bar{4}\cdot382$
70	$\bar{2}\cdot838$	$\bar{2}\cdot848$	$\bar{2}\cdot652$	$\bar{2}\cdot289$	$\bar{3}\cdot885$	$\bar{3}\cdot492$	$\bar{3}\cdot102$	$\bar{4}\cdot749$	$\bar{4}\cdot427$	$\bar{4}\cdot382$
75	$\bar{2}\cdot588$	$\bar{2}\cdot731$	$\bar{2}\cdot605$	$\bar{2}\cdot271$	$\bar{3}\cdot878$	$\bar{3}\cdot489$	$\bar{3}\cdot101$	$\bar{4}\cdot748$	$\bar{4}\cdot427$	$\bar{4}\cdot382$
80	$\bar{2}\cdot101$	$\bar{2}\cdot504$	$\bar{2}\cdot512$	$\bar{2}\cdot236$	$\bar{3}\cdot865$	$\bar{3}\cdot483$	$\bar{3}\cdot099$	$\bar{4}\cdot747$	$\bar{4}\cdot427$	$\bar{4}\cdot382$
84	$\bar{3}\cdot218$	$\bar{2}\cdot084$	$\bar{2}\cdot341$	$\bar{2}\cdot172$	$\bar{3}\cdot839$	$\bar{3}\cdot473$	$\bar{3}\cdot094$	$\bar{4}\cdot745$	$\bar{4}\cdot426$	$\bar{4}\cdot382$
86·5	$\bar{5}\cdot953$	$\bar{3}\cdot471$	$\bar{2}\cdot091$	$\bar{2}\cdot076$	$\bar{3}\cdot803$	$\bar{3}\cdot458$	$\bar{3}\cdot088$	$\bar{4}\cdot742$	$\bar{4}\cdot424$	$\bar{4}\cdot382$
88	$\bar{6}\cdot454$	$\bar{4}\cdot718$	$\bar{3}\cdot779$	$\bar{3}\cdot959$	$\bar{3}\cdot759$	$\bar{3}\cdot440$	$\bar{3}\cdot080$	$\bar{4}\cdot738$	$\bar{4}\cdot422$	$\bar{4}\cdot380$
90	$\overline{11}\cdot795$	$\bar{6}\cdot242$	$\bar{4}\cdot738$	$\bar{3}\cdot566$	$\bar{3}\cdot615$	$\bar{3}\cdot380$	$\bar{3}\cdot056$	$\bar{4}\cdot727$	$\bar{4}\cdot417$	$\bar{4}\cdot378$

Table 5D

Log $\Delta m_n - \beta F$ $\beta(3175) = 0{\cdot}425$

Z \ n	1	2	3	4	5	6	7	8	9	10
37°	$\bar{1}\cdot205$	$\bar{2}\cdot979$	$\bar{2}\cdot660$	$\bar{2}\cdot245$	$\bar{3}\cdot822$	$\bar{3}\cdot422$	$\bar{3}\cdot030$	$\bar{4}\cdot675$	$\bar{4}\cdot353$	$\bar{4}\cdot312$
60	$\bar{2}\cdot955$	$\bar{2}\cdot863$	$\bar{2}\cdot613$	$\bar{2}\cdot227$	$\bar{3}\cdot816$	$\bar{3}\cdot419$	$\bar{3}\cdot028$	$\bar{4}\cdot674$	$\bar{4}\cdot353$	$\bar{4}\cdot312$
70	$\bar{2}\cdot650$	$\bar{2}\cdot721$	$\bar{2}\cdot556$	$\bar{2}\cdot206$	$\bar{3}\cdot807$	$\bar{3}\cdot416$	$\bar{3}\cdot027$	$\bar{4}\cdot673$	$\bar{4}\cdot352$	$\bar{4}\cdot312$
75	$\bar{2}\cdot346$	$\bar{2}\cdot579$	$\bar{2}\cdot498$	$\bar{2}\cdot184$	$\bar{3}\cdot799$	$\bar{3}\cdot412$	$\bar{3}\cdot025$	$\bar{4}\cdot673$	$\bar{4}\cdot352$	$\bar{4}\cdot312$
80	$\bar{3}\cdot756$	$\bar{2}\cdot302$	$\bar{2}\cdot386$	$\bar{2}\cdot141$	$\bar{3}\cdot782$	$\bar{3}\cdot405$	$\bar{3}\cdot022$	$\bar{4}\cdot671$	$\bar{4}\cdot351$	$\bar{4}\cdot310$
84	$\bar{4}\cdot683$	$\bar{3}\cdot793$	$\bar{2}\cdot178$	$\bar{2}\cdot064$	$\bar{3}\cdot751$	$\bar{3}\cdot392$	$\bar{3}\cdot017$	$\bar{4}\cdot669$	$\bar{4}\cdot350$	$\bar{4}\cdot310$
86·5	$\bar{5}\cdot147$	$\bar{3}\cdot048$	$\bar{3}\cdot874$	$\bar{3}\cdot948$	$\bar{3}\cdot707$	$\bar{3}\cdot374$	$\bar{3}\cdot009$	$\bar{4}\cdot665$	$\bar{4}\cdot348$	$\bar{4}\cdot310$
88	$\bar{7}\cdot326$	$\bar{4}\cdot134$	$\bar{3}\cdot495$	$\bar{3}\cdot805$	$\bar{3}\cdot653$	$\bar{3}\cdot352$	$\bar{3}\cdot000$	$\bar{4}\cdot661$	$\bar{4}\cdot346$	$\bar{4}\cdot310$
90	$\overline{13}\cdot670$	$\bar{7}\cdot128$	$\bar{4}\cdot232$	$\bar{3}\cdot328$	$\bar{3}\cdot479$	$\bar{3}\cdot280$	$\bar{4}\cdot971$	$\bar{4}\cdot647$	$\bar{4}\cdot340$	$\bar{4}\cdot308$

Table 5D (contd.)

Log $\Delta m_n - \beta' F$ $\beta'(3399) = 0{\cdot}318$

Z \ n	1	2	3	4	5	6	7	8	9	10
37°	$\bar{1}{\cdot}334$	$\bar{1}{\cdot}096$	$\bar{2}{\cdot}771$	$\bar{2}{\cdot}354$	$\bar{3}{\cdot}930$	$\bar{3}{\cdot}529$	$\bar{3}{\cdot}137$	$\bar{4}{\cdot}782$	$\bar{4}{\cdot}460$	$\bar{4}{\cdot}417$
60	$\bar{1}{\cdot}146$	$\bar{1}{\cdot}009$	$\bar{2}{\cdot}736$	$\bar{2}{\cdot}340$	$\bar{3}{\cdot}925$	$\bar{3}{\cdot}527$	$\bar{3}{\cdot}136$	$\bar{4}{\cdot}781$	$\bar{4}{\cdot}460$	$\bar{4}{\cdot}417$
70	$\bar{2}{\cdot}918$	$\bar{2}{\cdot}903$	$\bar{2}{\cdot}693$	$\bar{2}{\cdot}324$	$\bar{3}{\cdot}919$	$\bar{3}{\cdot}525$	$\bar{3}{\cdot}134$	$\bar{4}{\cdot}781$	$\bar{4}{\cdot}459$	$\bar{4}{\cdot}417$
75	$\bar{2}{\cdot}691$	$\bar{2}{\cdot}797$	$\bar{2}{\cdot}650$	$\bar{2}{\cdot}308$	$\bar{3}{\cdot}912$	$\bar{3}{\cdot}522$	$\bar{3}{\cdot}134$	$\bar{4}{\cdot}780$	$\bar{4}{\cdot}459$	$\bar{4}{\cdot}417$
80	$\bar{2}{\cdot}249$	$\bar{2}{\cdot}589$	$\bar{2}{\cdot}566$	$\bar{2}{\cdot}276$	$\bar{3}{\cdot}900$	$\bar{3}{\cdot}517$	$\bar{3}{\cdot}131$	$\bar{4}{\cdot}779$	$\bar{4}{\cdot}459$	$\bar{4}{\cdot}417$
84	$\bar{3}{\cdot}447$	$\bar{2}{\cdot}209$	$\bar{2}{\cdot}411$	$\bar{2}{\cdot}218$	$\bar{3}{\cdot}877$	$\bar{3}{\cdot}507$	$\bar{3}{\cdot}127$	$\bar{4}{\cdot}777$	$\bar{4}{\cdot}458$	$\bar{4}{\cdot}417$
86·5	$\bar{4}{\cdot}297$	$\bar{3}{\cdot}651$	$\bar{2}{\cdot}183$	$\bar{2}{\cdot}131$	$\bar{3}{\cdot}844$	$\bar{3}{\cdot}493$	$\bar{3}{\cdot}121$	$\bar{4}{\cdot}775$	$\bar{4}{\cdot}457$	$\bar{4}{\cdot}415$
88	$\bar{6}{\cdot}935$	$\bar{4}{\cdot}967$	$\bar{3}{\cdot}900$	$\bar{2}{\cdot}024$	$\bar{3}{\cdot}804$	$\bar{3}{\cdot}477$	$\bar{3}{\cdot}114$	$\bar{4}{\cdot}772$	$\bar{4}{\cdot}455$	$\bar{4}{\cdot}415$
90	$\overline{10}{\cdot}702$	$\bar{6}{\cdot}718$	$\bar{4}{\cdot}954$	$\bar{3}{\cdot}667$	$\bar{3}{\cdot}673$	$\bar{3}{\cdot}423$	$\bar{3}{\cdot}093$	$\bar{4}{\cdot}761$	$\bar{4}{\cdot}450$	$\bar{4}{\cdot}412$

Table 6. $\Delta s - \Delta h$ for different Z and h

Layer(km.) \ n	1	2	3	4	5	6	7	8	9	Ozone amount in 10^{-3} cm/km y_n
					$Z = 37°$					
54–48	1·4	1·4	1·5	1·5	1·5	1·5	1·5	1·5	1·0	$y_9 =$
48–42	1·4	1·5	1·5	1·5	1·5	1·5	1·5	1·0	—	$y_8 =$
42–36	1·5	1·5	1·5	1·5	1·5	1·5	1·0	—	—	$y_7 =$
36–30	1·5	1·5	1·5	1·5	1·5	1·0	—	—	—	$y_6 =$
30–24	1·5	1·5	1·5	1·5	1·0	—	—	—	—	$y_5 =$
24–18	1·5	1·5	1·5	1·0	—	—	—	—	—	$y_4 =$
18–12	1·5	1·5	1·0	—	—	—	—	—	—	$y_3 =$
12– 6	1·5	1·0	—	—	—	—	—	—	—	$y_2 =$
6– 0	1·0	—	—	—	—	—	—	—	—	$y_1 =$
					$Z = 60°$					
54–48	5·7	5·7	5·7	5·8	5·8	5·9	5·9	5·9	4·0	$y_9 =$
48–42	5·7	5·7	5·8	5·8	5·9	5·9	5·9	4·0	—	$y_8 =$
42–36	5·7	5·8	5·8	5·9	5·9	5·9	4·0	—	—	$y_7 =$
36–30	5·8	5·8	5·9	5·9	5·9	4·0	—	—	—	$y_6 =$
30–24	5·8	5·9	5·9	5·9	4·0	—	—	—	—	$y_5 =$
24–18	5·9	5·9	5·9	4·0	—	—	—	—	—	$y_4 =$
18–12	5·9	5·9	4·0	—	—	—	—	—	—	$y_3 =$
12– 6	5·9	4·0	—	—	—	—	—	—	—	$y_2 =$
6– 0	4·0	—	—	—	—	—	—	—	—	$y_1 =$

Table 6 (contd.)

Layer(km.) \ n	1	2	3	4	5	6	7	8	9	Ozone amount in 10^{-3} cm/km y_n
$Z = 70°$										
54–48	10·5	10·6	10·7	10·9	11·0	11·1	11·3	11·4	7·6	$y_9 =$
48–42	10·6	10·7	10·9	11·0	11·1	11·3	11·4	7·6	—	$y_8 =$
42–36	10·7	10·9	11·0	11·1	11·3	11·4	7·6	—	—	$y_7 =$
36–30	10·9	11·0	11·1	11·3	11·4	7·6	—	—	—	$y_6 =$
30–24	11·0	11·1	11·3	11·4	7·6	—	—	—	—	$y_5 =$
24–18	11·1	11·3	11·4	7·6	—	—	—	—	—	$y_4 =$
18–12	11·3	11·4	7·6	—	—	—	—	—	—	$y_3 =$
12– 6	11·4	7·6	—	—	—	—	—	—	—	$y_2 =$
6– 0	7·6	—	—	—	—	—	—	—	—	$y_1 =$
$Z = 75°$										
54–48	14·9	15·2	15·4	15·6	16·0	16·2	16·5	16·8	11·4	$y_9 =$
48–42	15·2	15·4	15·6	16·0	16·2	16·5	16·8	11·4	—	$y_8 =$
42–36	15·4	15·6	16·0	16·2	16·5	16·8	11·4	—	—	$y_7 =$
36–30	15·6	16·0	16·2	16·5	16·8	11·4	—	—	—	$y_6 =$
30–24	16·0	16·2	16·5	16·8	11·4	—	—	—	—	$y_5 =$
24–18	16·2	16·5	16·8	11·4	—	—	—	—	—	$y_4 =$
18–12	16·5	16·8	11·4	—	—	—	—	—	—	$y_3 =$
12– 6	16·8	11·4	—	—	—	—	—	—	—	$y_2 =$
6– 0	11·4	—	—	—	—	—	—	—	—	$y_1 =$

Table 6 (contd.)

Layer(km.) \ n	1	2	3	4	5	6	7	8	9	Ozone amount in 10^{-3} cm/km y_n
$Z = 80°$										
54–48	22·1	22·7	23·4	24·0	24·8	25·6	26·5	27·3	18·8	$y_9 =$
48–42	22·7	23·4	24·0	24·8	25·6	26·5	27·3	18·8	—	$y_8 =$
42–36	23·4	24·0	24·8	25·6	26·5	27·3	18·8	—	—	$y_7 =$
36–30	24·0	24·8	25·6	26·5	27·3	18·8	—	—	—	$y_6 =$
30–24	24·8	25·6	26·5	27·3	18·8	—	—	—	—	$y_5 =$
24–18	25·6	26·5	27·3	18·8	—	—	—	—	—	$y_4 =$
18–12	26·5	27·3	18·8	—	—	—	—	—	—	$y_3 =$
12– 6	27·3	18·8	—	—	—	—	—	—	—	$y_2 =$
6– 0	18·8	—	—	—	—	—	—	—	—	$y_1 =$
$Z = 84°$										
54–48	31·0	32·4	34·0	35·8	37·8	40·2	43·0	46·4	33·2	$y_9 =$
48–42	32·4	34·0	35·8	37·8	40·2	43·0	46·4	33·2	—	$y_8 =$
42–36	34·0	35·8	37·8	40·2	43·0	46·4	33·2	—	—	$y_7 =$
36–30	35·8	37·8	40·2	43·0	46·4	33·2	—	—	—	$y_6 =$
30–24	37·8	40·2	43·0	46·4	33·2	—	—	—	—	$y_5 =$
24–18	40·2	43·0	46·4	33·2	—	—	—	—	—	$y_4 =$
18–12	43·0	46·4	33·2	—	—	—	—	—	—	$y_3 =$
12– 6	46·4	33·2	—	—	—	—	—	—	—	$y_2 =$
6– 0	33·2	—	—	—	—	—	—	—	—	$y_1 =$

Table 6 (contd.)

n Layer(km.)	1	2	3	4	5	6	7	8	9	Ozone amount in 10^{-3} cm/km y_n
$Z = 86\cdot5^\circ$										
54–48	37	40	42	46	50	55	62	72	57	$y_9 =$
48–42	40	42	46	50	55	62	72	57	—	$y_8 =$
42–36	42	46	50	55	62	72	57	—	—	$y_7 =$
36–30	46	50	55	62	72	57	—	—	—	$y_6 =$
30–24	50	55	62	72	57	—	—	—	—	$y_5 =$
24–18	55	62	72	57	—	—	—	—	—	$y_4 =$
18–12	62	72	57	—	—	—	—	—	—	$y_3 =$
12– 6	72	57	—	—	—	—	—	—	—	$y_2 =$
6– 0	57	—	—	—	—	—	—	—	—	$y_1 =$
$Z = 88^\circ$										
54–48	41	44	47	51	57	65	77	98	91	$y_9 =$
48–42	44	47	51	57	65	77	98	91	—	$y_8 =$
42–36	47	51	57	65	77	98	91	—	—	$y_7 =$
36–30	51	57	65	77	98	91	—	—	—	$y_6 =$
30–24	57	65	77	98	91	—	—	—	—	$y_5 =$
24–18	65	77	98	91	—	—	—	—	—	$y_4 =$
18–12	77	98	91	—	—	—	—	—	—	$y_3 =$
12– 6	98	91	—	—	—	—	—	—	—	$y_2 =$
6– 0	91	—	—	—	—	—	—	—	—	$y_1 =$

Table 6 (contd.)

n Layer(km.)	1	2	3	4	5	6	7	8	9	Ozone amount in 10^{-3} cm/km y_n
$Z = 90^\circ$										
54–48	42	46	50	55	62	72	89	125	222	$y_9 =$
48–42	46	50	55	62	72	89	125	222	—	$y_8 =$
42–36	50	55	62	72	89	125	222	—	—	$y_7 =$
36–30	55	62	72	89	125	222	—	—	—	$y_6 =$
30–24	62	72	89	125	222	—	—	—	—	$y_5 =$
24–18	72	89	125	222	—	—	—	—	—	$y_4 =$
18–12	89	125	222	—	—	—	—	—	—	$y_3 =$
12– 6	125	222	—	—	—	—	—	—	—	$y_2 =$
6– 0	222	—	—	—	—	—	—	—	—	$y_1 =$

and not by its distribution. 70°, 75°, 80°, 84°, 86·5°, 88° and 90° are convenient points to choose for fitting the curves.

2.1 *Correction for Secondary Scattering*

In the above, account is taken only of the primary scattered light from the molecules of the atmosphere. But the air is illuminated not only by direct sunlight but also by light scattered once or more by the rest of the atmosphere and by the ground. Neglect of the illumination of the air column by diffused light would be justified if the ratio of the intensities of the total scattered light of two different wave-lengths (which is the quantity actually measured) gave with sufficient accuracy the ratio of the primary scattered light of the same two radiations for different zenith distances of the sun.

A little consideration shows that this assumption is not justified. Of the light of two wave-lengths under comparison, one is much more absorbed by ozone than the other and, consequently, the contributions from the different layers of the atmosphere to the total primary scattered light from the zenith are different, and vary differently with the zenith distance of the sun. The multiple scattering which is dependent on the distribution in height of the primary scattered light will naturally differ for the two wave-lengths.

Let P, P' be the intensities of primary scattered light of the two wave-lengths λ, λ' from the zenith, and M, M' the intensities of the multiply scattered light.

The measurements with the spectrophotometer give $\log I/I'$ for different solar zenith distances.

Now

$$\frac{I}{I'} = \frac{P+M}{P'+M'} = \frac{P[1+(M/P)]}{P'[1+(M'/P')]}$$

We could correct the I/I' curve to give the P/P' curve if we knew the values of M/P and M'/P' for different zenith distances of the sun.

G. F. WALTON (1953) has calculated the intensities of primary (P) and secondary (S) scattered light from the zenith sky for different altitudes of the sun. After evaluating S/P for appropriate values of α and β for a few simple distributions of ozone, with total ozone amounts of 0·30 cm and 0·18 cm, he has calculated the corrections to be applied to the observed intensity-ratios to convert them to what they would be if there were only primary scattering. He found that the corrections varied with the zenith distance of the sun, but were nearly constant when $\sec Z$ was between 5 and 20. The effect of correcting for the secondary scattering was to lower the C.G. of the ozone by 2 to 3 km.

RAMANATHAN, MOORTY and KULKARNI (1952) obtained similar results by deriving umkehr curves for $I_{(3112)}/I_{(3075)}$ from observed umkehr curves of $I_{(3112)}/I_{(3323)}$ and $I_{(3075)}/I_{(3278)}$. The object of using the derived curve was to compare the intensities of two wave-lengths both of which are pretty strongly absorbed by ozone; in that case, the assumption $I/I' = P/P'$ would be more nearly correct. They came to the same conclusion as Walton viz., that the effect of taking multiple scattering into account was to increase the ozone amount in the layers below the maximum of ozone and to reduce it at higher levels.

Although there are still a few unsolved questions about the correction required for multiple scattering, it is believed that Table 7 provides, for different solar zenith distances, reasonable corrections when the ozone amount is between 0·18 cm and 0·30 cm.

Table 7. Correction for secondary scattering (Provisional). Amount to be *subtracted from* values of $N(Z)-N(60°)$ when observations are made with $C\lambda\lambda'$

Z	60°	70°	75°	80°	84°	86·5°	88°	90°
Subtract to correct for secondary scattering	0·0	1·0	2·0	4·5	6·0	6·0	6·0	6·0

Example

An example showing the calculation of log (I'/I) is given below. It relates to an umkehr curve obtained at Ahmedabad on 16 November 1956 with C pair of wavelengths. The total ozone amount was 0·192 cm. The values of N observed on light scattered from the clear zenith sky are given in Table 9B.

A trial distribution was assumed to start with; this was based on a general knowledge of average distribution corresponding to 0·192 cm. The values of y (in 10^{-3} cm/km) assumed to exist in layers 1 to 9, were

0, 0·5, 0·5, 5·5, 12·0, 8·0, 3·8, 1·4, 0·3.

In Table 8 is shown an example of calculating $Y = Y_n + x$, the total ozone in the path of the light when the zenith distance of the sun was 86·5°.

Table 8. Example showing calculation of ozone path Y for $Z = 86·5°$; $x = 0·192$ cm

Trial ozone distribution	y_1 0·0	y_2 0·5	y_3 0·5	y_4 5·5	y_5 12·0	y_6 8·0	y_7 3·8	y_8 1·4	y_9 0·3	y_{10} 0·0
Layer	1	2	3	4	5	6	7	8	9	10
9	·0111	·0120	·0126	·0138	·0150	·0165	·0186	·0216	·0171	·0000
8	·0560	·0588	·0644	·0700	·0770	·0868	·1008	·0798	·0000	·0000
7	·1596	·1748	·1900	·2090	·2356	·2736	·2166	·0000	·0000	·0000
6	·3680	·4000	·4400	·4960	·5760	·4560	·0000	·0000	·0000	·0000
5	·6000	·6600	·7440	·8640	·6840	·0000	·0000	·0000	·0000	·0000
4	·3025	·3410	·3960	·3135	·0000	·0000	·0000	·0000	·0000	·0000
3	·0310	·0360	·0285	·0000	·0000	·0000	·0000	·0000	·0000	·0000
2	·0360	·0285	·0000	·0000	·0000	·0000	·0000	·0000	·0000	·0000
1	·0000	·0000	·0000	·0000	·0000	·0000	·0000	·0000	·0000	·0000
Y_n	1·5642	1·7111	1·8755	1·9663	1·5876	0·8329	0·3360	0·1014	0·0171	0·0000
$Y = Y_n + x$	1·756	1·903	2·067	2·158	1·780	1·025	0·528	0·293	0·209	0·192

Similar calculations of Y_n and Y are to be made for other values of Z.

Using these values of Y and Form I, the values of log $(I'/I) = -L$ were computed for different values of Z. An example is shown for $Z = 86·5°$. As we are interested only in the relative values of L, or of N, which is equal to $100(L_0 - L)$, when Z changes, the computed value of 100 log(I'/I) at 60° has a correction added to it so that it becomes identical with the observed value of N at 60°. The same correction term is added to the computed values for all other angles also. We thus derive computed values of N which can be compared with the observed values. A sample calculation is shown below in Tables 9A and 9B and Forms I and II.

Table 9A. Trial distribution and changes in trial distribution. The y's are in units of 10^{-5} cm/km.

Layer	1	2	3	4	5	6	7	8	9
Total distribution	0·0	0·5	0·5	5·5	12·0	8·0	3·8	1·4	0·3
$\Delta y(a)$							—0·1		0·1
$\Delta y(b)$	0·5	0·5	2·0	—2·0	—1·0		—0·1		0·1
$\Delta y(c)$	0·5	1·5	1·0	—2·0	—1·0		—0·1		0·1
Final distribution	0·5	2·0	1·5	3·5	11·0	8·0	3·7	1·4	0·4

Table 9B. Observed and calculated values of N for different values of Z and for various ozone distributions

Z (degrees)	60	70	75	80	84	86·5	88	90
$Z^4 \times 10^{-7}$	1·30	2·40	3·16	4·10	4·98	5·60	6·00	6·56
Observed N	32·0	51·0	67·5	92·2	119·3	126·3	124·5	113·0
N according to trial distribution	32·0	52·7	70·4	96·5	120·6	127·0	123·2	108·9
$\Delta y(a)$	32·0				120·7	127·2	123·8	110·3
$\Delta y(b)$	32·0	51·8	69·0	93·9	118·3	127·0	124·9	112·2
$\Delta y(c)$	32·0	51·8	68·6	93·5	117·9	126·9	124·7	112·4

2.6 4.8 6.3 8.2 9.96 11.2 12.0 13.12

Table 9C. Example showing correction due to secondary scattering and its effect

Layer	1	2	3	4	5	6	7	8	9
y_n	2·0	2·0	3·0	3·7	10·0	7·0	3·2	0·9	0·2

Z (degrees)	60	70	75	80	84	86·5	88	90
Observed N corrected for Sec. Scatt.	32·0	50·0	65·5	87·7	113·3	120·3	118·5	107·0
Calculated N	32·0	51·0	66·5	89·0	111·6	120·5	119·2	106·5

Form I for computing log (I'/I) for given ozone distribution

Date: 16.10.56. Station: Ahmedabad. $Z = 86{\cdot}5°$ $\lambda/\lambda' = C$ $\alpha = 1{\cdot}23$ $\alpha' = 0{\cdot}08$ $x = 0{\cdot}192$ cm

n	1	2	3	4	5	6	7	8	9	10
y_n	0·0	0·5	0·5	5·5	12·0	8·0	3·8	1·4	0·3	—
Y_n										
x										
$Y = Y_n + x$	1·756	1·903	2·067	2·158	1·780	1·025	0·528	0·293	0·209	0·192
log $\Delta m_n - \beta F$	$\bar{6}{\cdot}728$	$\bar{4}{\cdot}828$	$\bar{3}{\cdot}761$	$\bar{3}{\cdot}881$	$\bar{3}{\cdot}657$	$\bar{3}{\cdot}331$	$\bar{4}{\cdot}968$	$\bar{4}{\cdot}625$	$\bar{4}{\cdot}309$	$\bar{4}{\cdot}267$
αY	2·160	2·341	2·543	2·654	2·189	1·261	0·649	0·360	0·257	0·236
D	$\bar{8}{\cdot}568$	$\bar{6}{\cdot}487$	$\bar{5}{\cdot}217$	$\bar{5}{\cdot}227$	$\bar{5}{\cdot}468$	$\bar{4}{\cdot}070$	$\bar{4}{\cdot}319$	$\bar{4}{\cdot}265$	$\bar{4}{\cdot}052$	$\bar{4}{\cdot}031$
antilog D	$\cdot 0_3 000$	$\cdot 0_3 003$	$\cdot 0_3 016$	$\cdot 0_3 017$	$\cdot 0_3 029$	$\cdot 0_3 118$	$\cdot 0_3 208$	$\cdot 0_3 184$	$\cdot 0_3 113$	$\cdot 0_3 107$

$D = \log \Delta m_n - \beta F - \alpha Y$. $\Delta I_n = K\beta$ antilog D. $I = \Sigma \Delta I_n = K\beta\ \Sigma$ antilog $D = 0{\cdot}0_3 795\ K\beta$.

log $\Delta m_n - \beta' F$	$\bar{5}{\cdot}953$	$\bar{3}{\cdot}471$	$\bar{2}{\cdot}091$	$\bar{2}{\cdot}076$	$\bar{3}{\cdot}803$	$\bar{3}{\cdot}458$	$\bar{3}{\cdot}088$	$\bar{4}{\cdot}742$	$\bar{4}{\cdot}424$	$\bar{4}{\cdot}382$
$\alpha' Y$	0·140	0·152	0·165	0·173	0·142	0·082	0·042	0·023	0·017	0·015
D'	$\bar{5}{\cdot}813$	$\bar{3}{\cdot}319$	$\bar{3}{\cdot}926$	$\bar{3}{\cdot}903$	$\bar{3}{\cdot}661$	$\bar{3}{\cdot}376$	$\bar{3}{\cdot}046$	$\bar{4}{\cdot}719$	$\bar{4}{\cdot}407$	$\bar{4}{\cdot}367$
antilog D'	$\cdot 0_2 007$	$\cdot 0_2 208$	$\cdot 0_2 843$	$\cdot 0_2 800$	$\cdot 0_2 458$	$\cdot 0_2 238$	$\cdot 0_2 111$	$\cdot 0_2 052$	$\cdot 0_2 026$	$\cdot 0_2 023$

$D' = \log \Delta m_n - \beta' F - \alpha' Y$. $\Delta I_n' = K\beta'$ antilog D'. $I' = \Sigma\ \Delta I_n' = K\ \beta'\ \Sigma$ antilog $D' = 0{\cdot}0277\ K\beta'$.

$\log I = \bar{4}{\cdot}900 + \log K\beta$. $\log I' = \bar{2}{\cdot}443 + \log K\beta'$. $\log(I'/I) = 1{\cdot}543 - \log(\beta/\beta') = 1.421$.
$100 \log(I'/I) = 142{\cdot}1$

The values of N calculated according to the trial distribution and adjusted so that the observed and calculated values coincide at 60°, are entered in row 4 of Table 9B. It will be noticed that the computed values are significantly lower at 90° and significantly higher at 75° and 80°. The first defect can be remedied by adding a small amount of ozone at the top. To remedy the second defect, some ozone has to be brought down from the middle layers to the bottom layers. These changes in distribution are made in successive approximation. Form II is used for computing changed $\log(I'/I)$.

Considering the scatter of values in the observed umkehr curve, it was considered that the values in the last row of Table 9B were sufficiently satisfactory and that the distribution given in the last row of Table 9A could be accepted as the distribution, *provided the zenith skylight was assumed to be due only to primary scattering.*

Form II for computing log (I'/I) for a changed initial distribution.

Date: 16.10.56. Station: Ahmedabad. $Z = 86\cdot5°$ $\lambda/\lambda' = C$ $\alpha = 1\cdot23$ $\alpha' = 0\cdot08$ $x = 0\cdot192$ cm.

n	1	2	3	4	5	6	7	8	9	10
Change in y_n	—	—	—	—	—	—	$-0\cdot1$	—	$+0\cdot1$	—
ΔY		$+0\cdot004$	$+0\cdot004$	$+0\cdot005$	$+0\cdot005$	$+0\cdot006$	$+0\cdot006$	$+0\cdot007$	$+0\cdot006$	$0\cdot000$
		$-0\cdot005$	$-0\cdot005$	$-0\cdot006$	$-0\cdot006$	$-0\cdot007$	$-0\cdot006$	—	—	—
		$-0\cdot001$	$-0\cdot001$	$-0\cdot001$	$-0\cdot001$	$-0\cdot001$	$0\cdot000$	$+0\cdot007$	$+0\cdot006$	$0\cdot000$
D (from Form I)		$\bar{6}\cdot487$	$\bar{5}\cdot217$	$\bar{5}\cdot227$	$\bar{5}\cdot468$	$\bar{4}\cdot070$	$\bar{4}\cdot319$	$\bar{4}\cdot265$	$\bar{4}\cdot052$	$\bar{4}\cdot031$
$\alpha\Delta Y$		$-0\cdot001$	$-0\cdot001$	$-0\cdot001$	$-0\cdot001$	$-0\cdot001$	$0\cdot000$	$+0\cdot009$	$+0\cdot007$	$0\cdot000$
$D-\alpha\Delta Y$		$\bar{6}\cdot488$	$\bar{5}\cdot218$	$\bar{5}\cdot228$	$\bar{5}\cdot469$	$\bar{4}\cdot071$	$\bar{4}\cdot319$	$\bar{4}\cdot256$	$\bar{4}\cdot045$	$\bar{4}\cdot031$
antilog $(D-\alpha\Delta Y)$	$\cdot0_3000$	$\cdot0_3003$	$\cdot0_3017$	$\cdot0_3017$	$\cdot0_3029$	$\cdot0_3118$	$\cdot0_3208$	$\cdot0_3180$	$\cdot0_3111$	$\cdot0_3107$

$$I = \Sigma\,\Delta I_n = K\beta\,\Sigma\,\text{antilog}(D-\alpha\Delta Y) = 0\cdot0_3790\,K\beta;\ \log I = \bar{4}\cdot898+\log K\beta.$$

D' (from Form 1)								$\bar{4}\cdot719$		
$\alpha'\Delta Y$		$0\cdot000$	$0\cdot000$	$0\cdot000$	$0\cdot000$	$0\cdot000$	$0\cdot000$	$+0\cdot001$	$0\cdot000$	$0\cdot000$
$D'-\alpha'\Delta Y$								$\bar{4}\cdot718$		
antilog$(D'-\alpha'\Delta Y)$								$\cdot0_2052$		

$$I' = \Sigma\,\Delta I_n' = K\beta'\,\Sigma\,\text{antilog}\,(D'-\alpha'\Delta Y) = 0\cdot0277\,K\beta';\ \ \log I' = \bar{2}\cdot443+\log K\beta'.$$

$$100\log(I'/I) = 142\cdot3$$

The observed values given in row 3 of Table 9B were corrected for secondary scattering according to Table 7. The new distribution to fit the corrected observed curve and the corresponding calculated values of N are given in Table 9C.

The following hints may be of some help in making the changes in distribution.

(1) With an assumed trial distribution, calculate $\log(I'/I)$ at $Z = 60°$. Add an appropriate constant to this so as to make it equal to the observed value of $N/100$ at 60°.

(2) Calculate $\log(I'/I)$ for 90° and 88°, and apply the same correction. If the calculated value is too high, remove a little ozone from the top layer to layer 6 or 7. If it is too low, add some ozone to the top. A small change at the top will make a large difference in $N(90°)$ and $N(88°)$. Get agreement at 88° and 90° to within 2 units of N.

(3) Calculate $\log(I'/I)$ for 86·5°, 84° and 75°, and add the same correction to each. Adjust ozone in the middle and lower layers so as to get satisfactory agreement at all the points.

3 Supplementary Tables for Use at Stations situated at about 912-mb Level and and at 810-mb Level

The main modifications in the tables for a station at $0{\cdot}9p_0$ (= 912 mb) and at $0{\cdot}8p_0$ (= 810 mb) are given below. It is assumed that the values of h in both these cases may be taken to be 3 km instead of 2 km. This is sufficiently accurate for the present purpose. The air mass in the first layer (ground to 6 km) should be changed as given in Table 2X.

If the pressure at the station-level is kp_0, the value of F is given by

$$F = k+(p/p_0)\times[\mathrm{Ch}(Z)-1].$$

The first row of Table 4 for F_h corresponding to the lowest layer is changed as shown in Table 4X. The values of F_h in all the other rows are decreased by 0·100 when the station is at or near 912 mb, and by 0·200 when it is at or near 810 mb.

For stations at or near 912 mb and 810 mb respectively, the values of $\log \Delta m_n - \beta F$ in the second column of tables 5A to 5D (corresponding to the lowest layer) require the changes given in Tables 5A(X) to 5D(X). For stations up to a height of 2·5 km, the tables for the nearest pressure-level may be used without appreciable error.

For the succeeding layers 2, 3, 4, etc., the values of $\log \Delta m_n - \beta F$ tabulated in Tables 5A to 5D should be increased by $(1-k)\beta$ for a station at pressure-level kp_0. Thus, for a station at 912-mb level, all the values in the third column of Table 5A should be increased by $0{\cdot}100\beta$, and for a station at the 810-mb level, by $0{\cdot}200\beta$. An example is given in Table 5A(Y) for the second and third layers.

The values of $\Delta s - \Delta h$ in the second column of Table 6 corresponding to the first layer requires a small and rather insignificant change, due to the raising of the centre of the layer from 2 to 3 km. These changes for each value of Z are tabulated in Table 6X.

It is recommended that each station should modify tables for regular use at the station.

Table 2X

p_0	$\log \Delta m_n$
1013 mb	$\bar{1}{\cdot}715$
912 mb	$\bar{1}{\cdot}622$
810 mb	$\bar{1}{\cdot}503$

The Δm's in the other layers remain the same as in Table 2.

Table 4X

p_0 mb	Z \ h	37°	60°	70°	75°	80°	84°	86·5°	88°	90°
1013	2	1·199	1·788	2·505	3·221	4·610	7·133	10·748	15·032	28·342
912	3	1·076	1·597	2·232	2·866	4·095	6·329	9·529	13·320	25·101
810	3	0·976	1·497	2·132	2·766	3·995	6·229	9·429	13·220	25·001

Table 5A(X). Log $\Delta m_n - \beta F$ for the lowest layer

Z	$\lambda = 3054$			$\lambda' = 3253$		
	1013 mb	912 mb	810 mb	1013 mb	912 mb	810 mb
37°	$\bar{1}$·112	$\bar{1}$·081	$\bar{1}$·012	$\bar{1}$·255	$\bar{1}$·209	$\bar{1}$·128
60	$\bar{2}$·816	$\bar{2}$·819	$\bar{2}$·750	$\bar{1}$·028	$\bar{1}$·009	$\bar{2}$·928
70	$\bar{2}$·455	$\bar{2}$·499	$\bar{2}$·431	$\bar{2}$·753	$\bar{2}$·765	$\bar{2}$·684
75	$\bar{2}$·095	$\bar{2}$·180	$\bar{2}$·112	$\bar{2}$·478	$\bar{2}$·521	$\bar{2}$·441
80	$\bar{3}$·396	$\bar{3}$·562	$\bar{3}$·494	$\bar{3}$·945	$\bar{2}$·050	$\bar{3}$·969
84	$\bar{4}$·127	$\bar{4}$·439	$\bar{4}$·370	$\bar{4}$·976	$\bar{3}$·192	$\bar{3}$·111
86·5	$\bar{6}$·309	$\bar{6}$·829	$\bar{6}$·760	$\bar{5}$·588	$\bar{5}$·963	$\bar{5}$·882
88	$\bar{8}$·154	$\bar{8}$·922	$\bar{8}$·853	$\bar{7}$·949	$\bar{6}$·507	$\bar{6}$·427
90	$\overline{15}$·459	$\overline{14}$·996	$\overline{14}$·927	$\overline{12}$·832	$\overline{11}$·983	$\overline{11}$·903

Table 5B(X). Log $\Delta m_n - \beta F$ for the lowest layer

Z	$\lambda = 3085$			$\lambda' = 3291$		
	1013 mb	912 mb	810 mb	1013 mb	912 mb	810 mb
37°	$\bar{1}$·138	$\bar{1}$·104	$\bar{1}$·034	$\bar{1}$·277	$\bar{1}$·229	$\bar{1}$·147
60	$\bar{2}$·855	$\bar{2}$·854	$\bar{2}$·783	$\bar{1}$·062	$\bar{1}$·039	$\bar{2}$·957
70	$\bar{2}$·510	$\bar{2}$·548	$\bar{2}$·478	$\bar{2}$·801	$\bar{2}$·807	$\bar{2}$·725
75	$\bar{2}$·166	$\bar{2}$·243	$\bar{2}$·173	$\bar{2}$·539	$\bar{2}$·576	$\bar{2}$·493
80	$\bar{3}$·498	$\bar{3}$·652	$\bar{3}$·581	$\bar{2}$·032	$\bar{2}$·127	$\bar{2}$·045
84	$\bar{4}$·284	$\bar{4}$·578	$\bar{4}$·507	$\bar{3}$·111	$\bar{3}$·312	$\bar{3}$·229
86·5	$\bar{6}$·545	$\bar{5}$·039	$\bar{6}$·968	$\bar{5}$·792	$\bar{4}$·144	$\bar{4}$·061
88	$\bar{8}$·485	$\bar{7}$·215	$\bar{7}$·144	$\bar{6}$·228	$\bar{6}$·760	$\bar{6}$·678
90	$\overline{14}$·082	$\overline{13}$·548	$\overline{13}$·478	$\overline{11}$·370	$\overline{10}$·460	$\overline{10}$·378

Table 5C(X). Log $\Delta m_n - \beta F$ for the lowest layer

Z	$\lambda = 3112$			$\lambda' = 3323$		
	1013 mb	912 mb	810 mb	1013 mb	912 mb	810 mb
37°	$\bar{1}$·159	$\bar{1}$·123	$\bar{1}$·050	$\bar{1}$·295	$\bar{1}$·245	$\bar{1}$·161
60	$\bar{2}$·885	$\bar{2}$·881	$\bar{2}$·808	$\bar{1}$·089	$\bar{1}$·063	$\bar{2}$·979
70	$\bar{2}$·553	$\bar{2}$·586	$\bar{2}$·514	$\bar{2}$·838	$\bar{2}$·841	$\bar{2}$·757
75	$\bar{2}$·220	$\bar{2}$·292	$\bar{2}$·220	$\bar{2}$·588	$\bar{2}$·619	$\bar{2}$·535
80	$\bar{3}$·576	$\bar{3}$·722	$\bar{3}$·649	$\bar{2}$·101	$\bar{2}$·189	$\bar{2}$·105
84	$\bar{4}$·405	$\bar{4}$·685	$\bar{4}$·613	$\bar{3}$·218	$\bar{3}$·407	$\bar{3}$·323
86·5	$\bar{6}$·728	$\bar{5}$·201	$\bar{5}$·128	$\bar{5}$·953	$\bar{4}$·287	$\bar{4}$·203
88	$\bar{8}$·740	$\bar{7}$·442	$\bar{7}$·369	$\bar{6}$·454	$\bar{6}$·960	$\bar{6}$·876
90	$\overline{14}$·564	$\overline{13}$·975	$\overline{13}$·903	$\overline{11}$·795	$\overline{10}$·837	$\overline{10}$·753

Table 5D(X). Log $\Delta m_n - \beta F$ for the lowest layer

Z	$\lambda = 3175$			$\lambda' = 3399$		
	1013 mb	912 mb	810 mb	1013 mb	912 mb	810 mb
37°	$\bar{1}$·205	$\bar{1}$·165	$\bar{1}$·088	$\bar{1}$·334	$\bar{1}$·280	$\bar{1}$·193
60	$\bar{2}$·955	$\bar{2}$·943	$\bar{2}$·867	$\bar{1}$·146	$\bar{1}$·114	$\bar{1}$·027
70	$\bar{2}$·650	$\bar{2}$·673	$\bar{2}$·597	$\bar{2}$·918	$\bar{2}$·912	$\bar{2}$·825
75	$\bar{2}$·346	$\bar{2}$·404	$\bar{2}$·327	$\bar{2}$·691	$\bar{2}$·711	$\bar{2}$·623
80	$\bar{3}$·756	$\bar{3}$·882	$\bar{3}$·805	$\bar{2}$·249	$\bar{2}$·320	$\bar{2}$·233
84	$\bar{4}$·683	$\bar{4}$·932	$\bar{4}$·856	$\bar{3}$·447	$\bar{3}$·609	$\bar{3}$·522
86·5	$\bar{5}$·147	$\bar{5}$·572	$\bar{5}$·496	$\bar{4}$·297	$\bar{4}$·592	$\bar{4}$·505
88	$\bar{7}$·326	$\bar{7}$·961	$\bar{7}$·884	$\bar{6}$·935	$\bar{5}$·386	$\bar{5}$·299
90	$\overline{13}$·670	$\overline{12}$·954	$\overline{12}$·878	$\overline{10}$·702	$\bar{9}$·640	$\bar{9}$·553

Table 5A(Y). Log $\Delta m_n - \beta F$ for second and higher layers for a station at 810 mb

	$\lambda = 3054 \quad 0{\cdot}200\beta = 0{\cdot}101$			$\lambda' = 3253 \quad 0{\cdot}200\beta' = 0{\cdot}077$		
Z \ n	2	3	etc. ...	2	3	etc. ...
37°	$\bar{2}$·995	$\bar{2}$·680		$\bar{1}$·101	$\bar{2}$·780	
60	$\bar{2}$·857	$\bar{2}$·625		$\bar{2}$·996	$\bar{2}$·737	
70	$\bar{2}$·689	$\bar{2}$·557		$\bar{2}$·868	$\bar{2}$·685	
75	$\bar{2}$·521	$\bar{2}$·489		$\bar{2}$·739	$\bar{2}$·633	
80	$\bar{2}$·194	$\bar{2}$·355		$\bar{2}$·489	$\bar{2}$·532	
84	$\bar{3}$·591	$\bar{2}$·110		$\bar{2}$·029	$\bar{2}$·344	
86·5	$\bar{4}$·710	$\bar{3}$·750		$\bar{3}$·356	$\bar{2}$·069	
88	$\bar{5}$·628	$\bar{3}$·302		$\bar{4}$·530	$\bar{3}$·727	
90	$\bar{8}$·070	$\bar{5}$·806		$\bar{7}$·814	$\bar{4}$·586	

Table 6X. $\Delta s - \Delta h$ for the first layer when the centre is at 3 km

Layer(km) \ Z	37°	60°	70°	75°	80°	84°	86·5°	88°	90°
54–48	1·4	5·7	10·5	14·9	22·1	31·1	37	42	43
48–42	1·4	5·7	10·6	15·2	22·7	32·6	40	45	47
42–36	1·4	5·8	10·7	15·4	23·4	34·2	43	48	51
36–30	1·4	5·8	10·9	15·7	24·2	36·1	46	52	56
30–24	1·5	5·8	11·0	16·0	24·9	38·2	51	58	63
24–18	1·5	5·9	11·1	16·3	25·8	40·6	56	67	74
18–12	1·5	5·9	11·3	16·5	26·6	43·6	63	79	93
12– 6	1·5	5·9	11·5	16·9	27·5	47·0	75	103	137
6– 0	0·8	3·0	5·7	8·5	14·1	25·1	43	71	193

Form I for computing log (I'/I) for given ozone distribution.

Date: Station: $Z =$ $\lambda/\lambda' =$ $\alpha =$ $\alpha' =$ $x = 0.$ cm

n	1	2	3	4	5	6	7	8	9	10
y_n										
Y_n										
x										
$Y = Y_n + x$										
$\log \Delta m_n - \beta F$										
αY										
D										
antilog D										

$D = \log \Delta m_n - \beta F - \alpha Y.$

$\Delta I_n = K\beta$ antilog D.

$I = \Sigma \Delta I_n = K\beta \Sigma$ antilog $D =$ $K\beta$.

$\log \Delta m_n - \beta' F$										
$\alpha' Y$										
D'										
antilog D'										

$D' = \log \Delta m_n - \beta F - \alpha' Y.$

$\Delta I_n' = K\beta'$ antilog D'.

$I' = \Sigma \Delta I_n' = K\beta' \Sigma$ antilog $D' =$ $K\beta'$.

$\log I =$ $+ \log K\beta.$ $\log(I'/I) =$ $-\log(\beta/\beta') =$

$\log I' =$ $+ \log K\beta'.$

$100 \log(I'/I) =$

Form II for computing $\log(I'/I)$ for a changed initial distribution.

Date; Station: $Z =$ $\lambda/\lambda' =$ $\alpha =$ $\alpha' =$ $x = 0.$ cm

n	1	2	3	4	5	6	7	8	9	10
Change in y_n										
ΔY										
D (from Form I)										
$\alpha \Delta Y$										
$D - \alpha \Delta Y$										
antilog$(D - \alpha \Delta Y)$										

$I = \Sigma \Delta I_n = K\beta \Sigma$ antilog$(D - \alpha \Delta Y) =$ $K\beta$; $\log I =$ $+\log K\beta$.

D' (from Form I)										
$\alpha' \Delta Y$										
$D' - \alpha' \Delta Y$										
antilog$(D' - \alpha' \Delta Y)$										

$I' = \Sigma \Delta I_n' = K\beta' \Sigma$ antilog $(D' - \alpha' \Delta Y) =$ $K\beta'$; $\log I' =$ $+\log K\beta'$.

$100 \log(I'/I) =$

Form III

Station:
$x = 0$ cm

Date:
$\lambda/\lambda' =$

Trial Distributions

Layer	1	2	3	4	5	6	7	8	9
Trial Distn. y									
$\Delta y(a)$									
$\Delta y(b)$									
$\Delta y(c)$									
$\Delta y(d)$									
$\Delta y(e)$									
Final Distn.									

Observed and Calculated N

Z (degrees) $Z^4 \times 10^{-7}$	60 1·30	70 2·40	75 3·16	80 4·10	84 4·98	86·5 5·60	88 6·00	90 6·56
Observed N								
Calculated N Trial distn.								
Ditto $\Delta y(a)$								
Ditto $\Delta y(b)$								
Ditto $\Delta y(c)$								
Ditto $\Delta y(d)$								
Ditto $\Delta y(e)$								

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