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Determination of ozone amounts from zenith sky observations

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ABSTRACT. The total amounts of ozone are normally determined from direct sun observations with the help of a Dobson's spectrophotometer. In this paper preparation of zenith sky charts from zenith sky ozone observations has been explained. It has been shown that on occasions when ozone observations from direct sunlight are not possible due to clouds covering the sun, ozone amounts can be determined with reasonable degree of accuracy from zenith sky observations with the help of these zenith sky charts.

1. Introduction

In view of the important role played by ozone, acting as a tracer in the upper atmosphere, the study of the behaviour of ozone in the atmosphere is being actively pursued by meteorologists all over the world. For a study of this kind, it is necessary to have unbroken records of total ozone amount, measured by a standard instrument like Dobson's spectrophotometer, employing A, B, C or D pair of wavelengths, measurements being made with direct sunlight. There is, however, some difficulty in the measurements of ozone amounts when the sky is clouded with high, medium or low clouds. Therefore Dobson suggested that total ozone amounts under cloudy sky conditions could be determined by preparing cloud charts from the zenith sky observations. Errors in such measurements, however, cannot be completely eliminated as has been discussed by Tonsberg and Olsen (1944), Langlo (1952) and others.

In India, recently Shah (1961) has prepared cloud charts with zenith sky observations made at Mt. Abu (Lat. 24·6°N, Long. 72·7°E). The purpose of the present communication is to present the zenith sky charts (prepared with the observations taken at New Delhi (Lat. 28·6°N, Long. 77·2°E) during 1952-53 using $C\lambda\lambda$, and for the year 1963-64 on $AD\lambda\lambda$ for the determination of total ozone amount.

2. Data used

Continuous zenith sky observations on some selected days during 1952-53 using $C\lambda\lambda$ under clear and cloudy sky conditions have been taken for different values of μ (μ=1 when sun's zenith distance =0, μ being relative path-length of sunlight through the ozone layer). The details are given below—

Zenith condition	Date	Ozone amount (cm)
1. Clear sky	12-11-52 (AN)	0·165
	30 - 1-53 (AN)	0·200
	1 - 2-53 (AN)	0·225
2. Cloudy sky		
(*a*) High clouds	17-12-52 (AN)	0·170
	16-12-52 (AN)	0·185
	18 - 1-53 (AN)	0·210
	22 - 1-53 (FN)	0·220
(*b*) Low/Medium clouds		
	21-12-52 (AN)	0·160
	28 - 1-53 (AN)	0·210
	20 - 1-53 (AN)	0·225

The result of the observations has been presented graphically in Figs. 1 to 3.

Similar observations using $AD\lambda\lambda$ during 1963-64 have been made. The results have been summarised and shown in Tables 1

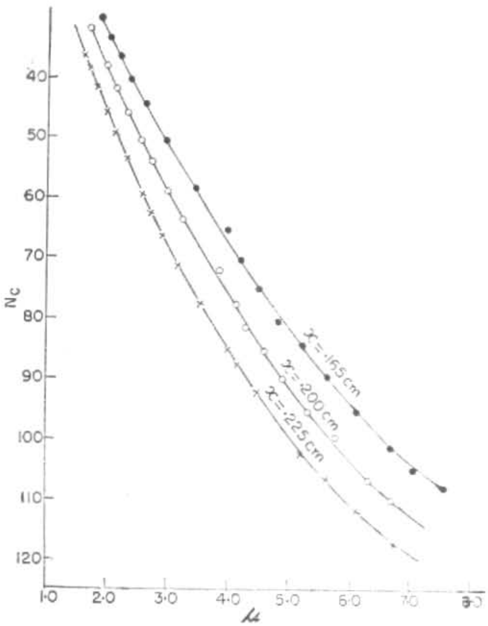

Fig. 1. Zenith sky chart on clear sky ($C\ \lambda\lambda$)

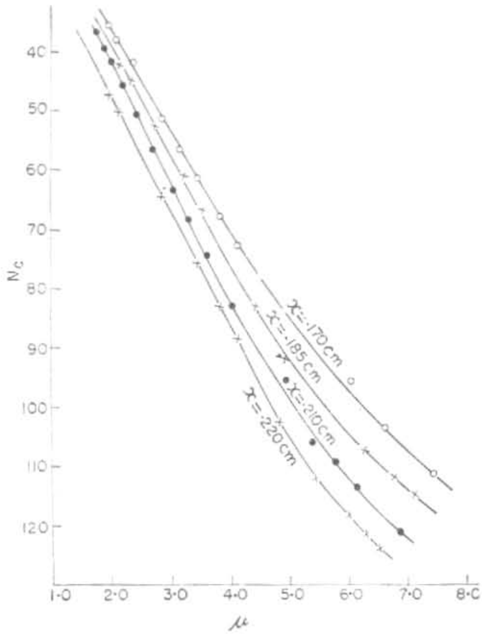

Fig. 2. Zenith sky chart on high clouds ($C\ \lambda\lambda$)

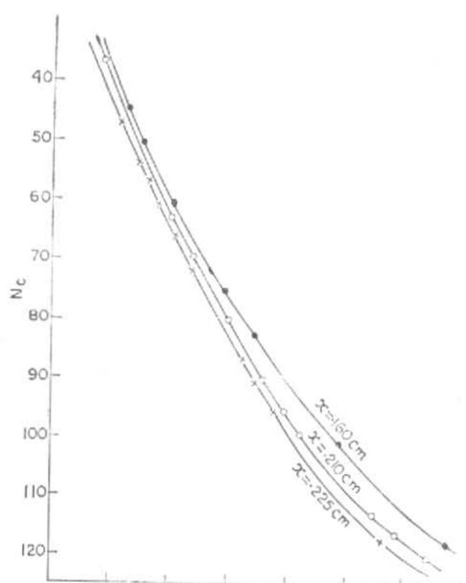

Fig. 3. Zenith sky chart on low/medium clouds ($C\ \lambda\lambda$)

TABLE 1

(Clear zenith)

Serial No.	Date	Time (IST)	μ	$\frac{N_{AD}}{\mu}$	X_{AD} from cloud chart	X_{AD} from direct sun observation	Difference (7)—(6)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	17-12-63	0834	3·611	·3380	·281	·279	—·002
2	18-12-63	1012	1·980	·4009	·285	·282	—·003
3	23-12-63	0920	2·572	·4134	·311	·311	000
4	10-1-64	0906	2·890	·3552	·268	·269	+·001
5	16-1-64	0903	2·922	·4160	·315	·315	000
6	17-1-64	0904	2·890	·4190	·317	·313	—·004
7	18-1-64	0902	2·906	·3755	·308	·300	—·008
8	19-1-64	0902	2·914	·3873	·295	·292	—·003
9	28-1-64	1530	2·206	·3755	·275	·275	000
10	28-1-64	1620	3·144	·3517	·278	·274	—·004
11	18-2-64	1530	1·895	·4365	·311	·303	—·008
12	18-2-64	1630	2·874	·3950	·305	·307	+·002
13	21-2-64	1529	1·857	·4305	·307	·305	—·002
14	21-2-64	1629	2·715	·4115	·312	·303	—·009
						Average difference =	·003

and 2 and also in Figs. 4 to 6. The details of the Figs. 4 to 6 are given below—

Zenith condition	Date	Ozone amount (cm)
1. Clear sky	19-1-64 (AN)	0·273
	2-1-64 (AN)	0·296
	13-1-64 (AN)	0·307
2. Cloudy sky		
(*a*) High clouds		
	6-2-64 (AN)	0·322
	2-2-64 (AN)	0·336
	3-2-64 (AN)	0·387
(*b*) Low/Medium clouds		
	17-2-64 (AN)	0·295
	8-2-64 (AN)	0·320
	10-2-64 (FN)	0·336

3. Discussion

Figs. 1 to 3 have been prepared with N_C, where $N_C = 100\ (L_0 - L)$, as ordinate and μ as abscissa. With such a cloud chart (called empirical cloud chart), it is possible to find out the total amount of ozone from a knowledge of N_C and μ under any condition of the sky. These charts are very useful for days having average values of ozone, but on occasions when the amounts of ozone are well above or well below the average values, extrapolation may not give very accurate result.

In order to obviate this difficulty Dobson and Normand (1958) suggested that cloud charts might be prepared from the zenith sky observations based on a pair of wavelengths (*viz.*, AD $\lambda\lambda$). They also suggested that in such charts instead of taking N_{AD}

TABLE 2

(Cloudy zenith)

Serial No.	Date	Time (IST)	μ	$\frac{N_{AD}}{\mu}$	X_{AD} from cloud chart	X_{AD} from direct sun observation	Difference (7)—(6)	Type of cloud over zenith
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	12-12-63	1036	1·810	·3985	·283	·284	+·001	*Sc*
2	25-12-63	0955	2·155	·4154	·301	·308	+·007	*Ci*
3	26-12-63	0953	2·187	·3812	·277	·289	+·012	*Ci*
4	26-12-63	1442	2·022	·4048	·290	·278	—·012	*Ci*
5	29-12-63	0908	2·851	·4031	·286	·284	—·002	*Cs*
6	6-1-64	0902	2·964	·3566	·276	·271	—·005	*Sc*
7	7-1-64	0858	3·088	·3531	·272	·264	—·008	*Cs*
8	7-1-64	1541	2·964	·3498	·274	·269	—·005	*Cs*
9	8-1-64	0907	2·898	·3478	·265	·268	+·003	*Ac*
10	8-1-64	1450	2·068	·3711	·268	·268	000	*Ac*
11	10-1-64	1408	1·782	·3903	·277	·274	—·003	*Sc*
12	11-1-64	0858	3·154	·3468	·270	·274	—·004	*Sc*
13	11-1-64	1549	2·851	·3775	·285	·276	—·009	*Sc*
14	20-1-64	1452	1·949	·4031	·286	·296	+·010	*Ci*
15	21-1-64	1006	1·991	·4179	·300	·309	+·009	*Sc*
16	6-2-64	0847	2·956	·4189	·319	·326	+·007	*As*
17	9-2-64	0950	1·934	·4535	·324	·321	—·003	*Ac, As*
18	10-2-64	0903	2·510	·4694	·343	·333	—·010	*Sc, As*
19	13-2-64	1001	1·788	·4451	·315	·313	—·002	*As*
20	17-2-64	1241	1·323	·4268	·295	·296	+·001	*Sc, St*
21	17-2-64	1631	2·835	·3960	·300	·292	—·008	*As*

Average difference = ·006

as ordinate, N_{AD}/μ, where $N_{AD}=(L_{0A}-L_{0D})-(L_A-L_D)$, should be taken as ordinate and μ as abscissa. In this method, as the lines of ozone amounts have less slopes, a more open ordinate scale can be used since the range is smaller. The cloud charts based on observations with *AD* wavelengths and constructed on the above lines have been presented in Figs. 4 to 6. The values of ozone contents are also shown in the figures. These values have been obtained from direct sun observations. The ozone values shown in Figs. 4 to 6 were determined by using Vigroux's (1953) constants, whereas those shown in Figs. 1 to 3 were determined using Nye Choong's (1932) constants.

From theoretical considerations, by neglecting the effect of multiple scattered light it can be shown that the separation of the lines of equal values of ozone at $\mu=1$ should be equal to $(\alpha-\alpha')_{AD}$ where $(\alpha-\alpha')_{AD}$ is the difference between the absorption coefficients of ozone on *A* and *D* pair of wavelengths. In zenith

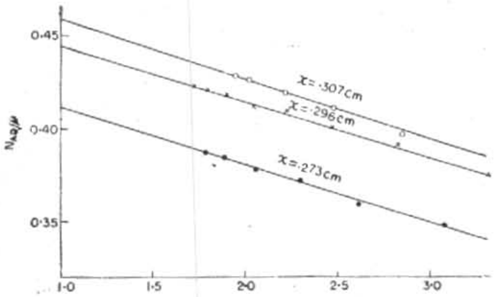

Fig. 4. Zenith chart on clear sky ($AD\ \lambda\lambda$)

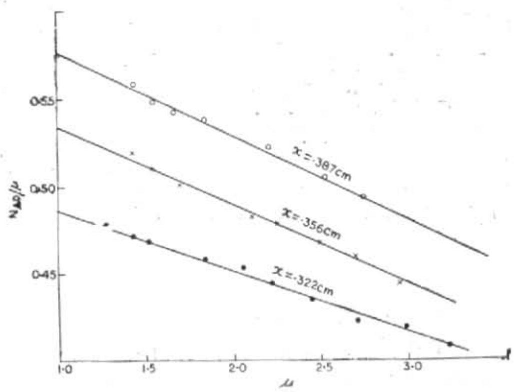

Fig. 5. Zenith sky chart on high clouds ($AD\ \lambda\lambda$)

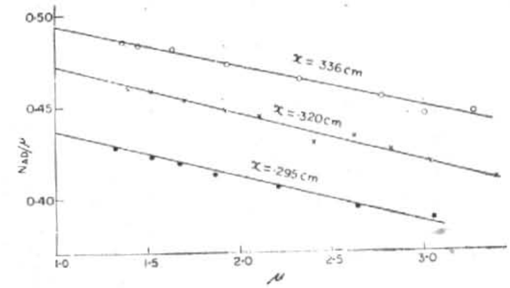

Fig. 6. Zenith sky chart on low/medium clouds ($AD\ \lambda\lambda$)

sky charts (Figs. 4 to 6) this difference has been nearly maintained.

Zenith sky charts on measurements can also be prepared with N_C/μ as ordinate and μ as abscissa, but the separation of the lines of equal values of ozone at $\mu=1$ in these charts may not be equal to $(\alpha-\alpha')\lambda\lambda C$ probably due to haze correction (Ramanathan and Karandikar 1949) application in the ozone amount determination formula for direct sun observations on C setting.

It may, however, be mentioned that the days with very high or very low amounts of ozone on clear or cloudy zenith sky conditions are very rare. For this reason it is rather difficult to draw the lines having very high or very low values of ozone. However this difficulty can be eliminated by extrapolation, giving reasonable degree of accuracy.

In order to find out the degree of accuracy, the difference between the observed values of ozone by direct sun method and those calculated from cloud charts from the zenith sky observations taken simultaneously on different days at different hours, have been found and shown in col. 8 of Tables 1 and 2 for clear and cloudy zenith sky conditions respectively. It is seen from Table 1 that under clear sky conditions the average difference is of the order of ·003 cm. The average difference for the cloudy zenith sky conditions irrespective of types of clouds, comes out to be about ·006 cm.

It is thus seen from a knowledge of N_{AD}/μ and μ, the amount of ozone can be measured with the help of empirical cloud chart presented here with a reasonable degree of accuracy, even when the zenith sky is covered with high, medium or low clouds.

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