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INTERCALIBRATION OF DOBSON OZONE SPECTROPHOTOMETERS IN THE INDIAN NETWORK (1978-80)

1. Atmospheric ozone measurements using Dobson Ozone Spectrophotometers (D.O.S.) are being made at the six stations in India listed below:

Station		*D.O.S. No.*
Srinagar	(34°05′ N, 74°50′E)	10
New Delhi	(28°35′ N, 77°12′E)	36
Varanasi	(25°18′ N, 83°01′E)	55
Mt. Abu	(24°36′ N, 72°43′E)	54
Pune	(18°32′ N, 73°51′E)	39
Kodaikanal	(10°14′ N, 77°28′E)	45

In addition to these six instruments, Dobson Ozone Spectrophotometer No. 112, which has now been designated by W.M.O. as one of the seven Secondary Reference Standard Spectrophotometers is maintained at New Delhi. This instrument took part in the International Comparison of Dobson Ozone Spectrophotometers held in Belsk, Poland in July 1974. Within two years of the Belsk Comparisons a comprehensive programme for complete overhaul, electro-mechanical modernisation, optical adjustments and intercalibration of all the six field Dobson Instruments in Indian network against the standard instrument No. 112 was completed to upgrade the quality of ozone data. This was duly reported in the International Ozone Symposium co-sponsored by W.M.O. and International Ozone Commission held at Dresdan, August 1976 (Chopra *et al.* Proc. of the International Ozone Symp. Aug 1976, Vol 1).

2. In continuation of India's co-operation as envisaged by W.M.O. under its "Global Ozone Monitoring and Research Project", Dobson instrument No. 112, the standard for India again took part in the Dobson spectrophotometer intercomparison held at Boulder in August 1977 under the auspices of W.M.O. Within the period from 1978 to April 1980 all the six field instruments in India were again optically re-adjusted and intercalibrated against the Secondary Reference Standard instrument No. 112 as required by CIMO working group on measurement of atmospheric ozone at its meeting at Hohenpiessenberg, during 17-21 April 1978.

3. All the six instruments were brought to New Delhi one at a time and preliminary comparison with the standard No. 112 was done to assess the corrections to the N-value of each instrument and to the past ozone data. This was also useful in study of the drift in the instrument since the past intercalibration during 1974-76. The results of the preliminary comparison are given in Table 1.

TABLE 1

Corrections to N and X_{AD} values obtained after preliminary comparison with Spectrophotometer No. 112 as the reference instrument

Inst. No.	Date of comparison	Average N-value corrections N_A	N_C	N_D	Corrections to X_{AD} in μ 1.2– 3.0
10	12 Oct 78	0.029	0.038	0.055	–3.2
36	11 Oct 79	–0.015	–0.001	–0.003	1.5
39	8 Sep 79	0.048	0.051	0.038	1.2
45	30 Mar 78	0.006	0.047	0.005	0.3
54	3 Mar 80	–0.024	–0.021	–0.025	0.5
55	7 Apr 80	0.048	0.042	0.022	3.8

4. IP 28 photomultipliers in all the instruments were replaced by EMI photomultipliers. All the optical re-adjustments, tests and calibrations which were mandatory for instruments participating in the WMO Dobson Ozone Spectrophotometer Intercomparison, Boulder 1977 to qualify as regional Secondary Reference Standards were performed on each instrument. Optical alignments as previously carried out were found to be mostly satisfactory except that slit S_1 and S_2 were non-parallel in all the instruments. In the process of setting the slits parallel slight re-adjustments of mirrors M_1 and M_2 had to be done. After the optical wedge calibration by "two lamp" method provisional wedge tables were made to give the values of N (or G) against the dial readings. Comparisons of each instrument against the standard instrument No. 112 were carried out on two or more occasions to determine the corrections to the N-values of the provisional wedge tables. The result of the comparison for the days when standard lamp tests before and after the comparisons showed consistant results were taken for analysing the corrections. Individual series of $\triangle N_i = N_i - N_{112}$ for each instrument whose number is denoted by i and for each wavelength pair C, A and D were obtained on comparison with No. 112. To each set of values a straight line was fitted by least squares to $\triangle N$ as a function of μ and the residuals were examined. As the residuals of all observations were less than .01 there were no rejections. The results are shown in Table 2.

As seen from Table 2 the standard deviation averaged over all $\lambda\lambda$ in case of all the instruments is below 3.5×10^{-3}. Correlation with μ is also generally insignificant except in case of No. 10 on $\lambda\lambda C$, No. 36 on $\lambda\lambda D$, No. 45 on $\lambda\lambda C$, and No. 55 on $\lambda\lambda C$.

5. Such significant correlation as in the case of No. 10 could be due to pronounced internal scattering of light or error in the wedge calibration,

TABLE 2

Parameter	Instrument No. 10	36	39	45	54	55
			λλC			
n	17	42	24	16	18	19
$\overline{\triangle N}$	80.94	19.21	60.33	24.38	20.89	4.90
σ	4.408	2.590	1.857	1.310	2.143	2.052
σ_{res}	1.693	2.558	1.761	0.804	2.130	1.550
b	−8.787	0.109	−0.898	−1.653	−0.163	2.359
σ_b	1.802	2.621	1.839	0.859	2.259	1.638
μ	2.078	1.866	1.822	1.839	1.744	1.911
r	−0.918	0.026	−0.248	−0.774	−0.043	0.631
			λλA			
n	37	84	48	31	34	40
$\overline{\triangle N}$	88.24	38.0	43.23	36.07	10.71	7.7
σ	2.688	2.720	3.397	3.521	2.960	2.103
σ_{res}	2.178	2.475	3.329	2.914	2.913	1.959
b	−3.254	−1.831	0.947	−3.198	−0.240	1.326
σ_b	2.239	2.505	3.401	3.013	3.003	2.010
μ	2.041	1.836	1.799	1.813	1.758	1.876
r	−0.533	−0.403	0.139	−0.541	−0.044	0.331
			λλD			
n	18	42	23	16	18	22
$\overline{\triangle N}$	8.794	6.19	42.0	40.63	26.78	14.59
σ	2.578	2.634	3.261	2.527	2.439	2.197
σ_{res}	1.970	1.958	3.106	2.241	1.972	1.772
b	−3.655	−2.883	1.495	−1.701	2.425	−2.357
σ_b	2.089	2.006	3.250	2.396	2.092	1.858
μ	2.051	1.836	1.774	1.816	1.725	1.886
r	−0.618	−0.659	0.228	−0.401	0.554	−0.564

The units of N is 0.001 log units.

[The notation used in Table 2 are :

n = The number of observations used,

$\overline{\triangle N}$ = The mean value of $\triangle N$,

σ = The standard deviation before fitting a straight line,

σ_{res} = The standard deviation of residuals scatter after fitting a straight line,

b = The slope of the line,

σ_b = The standard error of the estimate of b,

r = Correlation coefficient]

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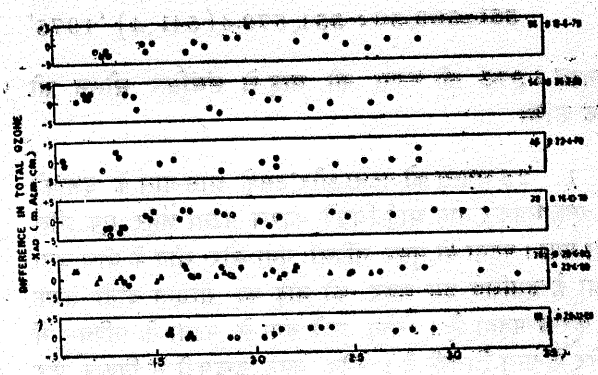

Fig. 1. Difference in total ozone amount ($\Delta D\lambda\lambda$) from instrument No. 112

These will be examined again after a new wedge calibration. After incorporating corrections equal to $\overline{\triangle N}$ to the value of N of the provisional tables, final wedge tables were prepared for conversion of R to N values. Ozone values (X_{AD}) were obtained from direct sun measurements during the comparison. Fig. 1 shows the difference of total ozone amounts (X_{AD}) given by each instrument from those given by the standard No. 112. The difference from No. 112 is satisfactorily small (within ‘4 m. atm. cm). The average total ozone values (X_{AD}) yielded by all the instruments in the μ range of 3.0 to 1.2 are within $\pm$0.3 per cent of the values given by the standard instrument No. 112.

After bringing all the Dobson instruments in the Indian network to yield strictly comparable ozone values, continuous monitoring of their performance, routine tests and maintenance are being carried out from the National Ozone Centre at New Delhi.

6. The work of intercalibration of Dobson Ozone Spectrophotometers in the National network was taken up as a part of the programme of the National Ozone Centre, in the office of the Dy. Director General of Meteorology (Instrument Production). The authors express their grateful thanks to the Dy. Director General of Meteorology (IP) for his support and encouragement for this work. Thanks are also due to the colleagues of the National Ozone Centre, New Delhi and the ozone field stations for their valuable assistance and co-operation in the important project.

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