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Atmospheric turbidity measurements over India

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ABSTRACT. From daily measurements of direct solar radiation for selected spectral regions and for the whole spectrum, coefficients of atmospheric turbidity and transmissivity have been calculated for different months for two representative stations in north and central India. Attenuation of direct solar radiation and atmospheric turbidity are maximum at both stations, during the hot, dry, dusty summer months and a minimum during the monsoon months and after, when the atmosphere has been cleansed of its dust content by precipitation. The turbidity over Delhi is two to five times that over Poona throughout the year, as a result of its proximity to the arid zones to the west. The variations from year to year are also much more pronounced at Delhi. The sudden fall in turbidity during June as well as the turbidity values during June to September at both stations are related to the times of onset of the monsoon in the two areas and the amount of rainfall during these months.

1. Introduction

Measurements of the intensity of direct solar radiation at normal incidence in selected spectral regions and in the entire spectrum are of great importance in meteorological and geophysical studies and in the analysis of the attenuation of radiation within the atmosphere by scattering and absorption. They also provide the means for the determination of atmospheric turbidity and the magnitude of the aerosol and water vapour content of the atmosphere.

Measurements of direct solar radiation in the entire spectrum and for selected spectral regions using Schott glass filters OG_1, RG_2 and RG_8, have been made at Delhi since 1955 and at Poona since 1957 with Ångström pyrheliometers. Preliminary results of these studies made during the IGY were presented by Mani and Chacko (1963 a). The present paper summarises the results of observations of direct solar radiation made at Delhi and Poona during the five years 1958 to 1962 and discusses the annual, seasonal and diurnal variations of the solar intensity, the transmission coefficient and the atmospheric turbidity as well as their variations from year to year.

2. Coefficient of turbidity β

The method of measurement of the intensity of solar radiation at normal incidence using Ångström Compensation pyrheliometers is well known. By isolating the red and infrared regions of the spectrum, where absorption by water vapour is considerable from the ultraviolet and visible regions ($\lambda < .630\ \mu$), where attenuation is due mainly to scattering by air molecules and aerosols, a turbidity factor for the atmosphere can be computed. The relation for the extinction of solar radiation in the ultraviolet and visible region is given by (IGY Instr. Manual 1957) —

$$I_k = \frac{1}{S}\int_0 0{\cdot}630\, I_o\,(\lambda)\, e^{-m\times 0\cdot 00897\,\lambda^{-4\cdot 09}} \times e^{-mh}\, \beta\lambda^{-\alpha}\, d\lambda \qquad (1)$$

where, $I_o\ (\lambda)$ = solar intensity outside the atmosphere as a function of wavelength

I_k = solar radiation intensity for $\lambda < \cdot 630\mu$,

S = reduction factor for the mean sun-earth distance,

m = optical airmass, and

m_h = relative airmass

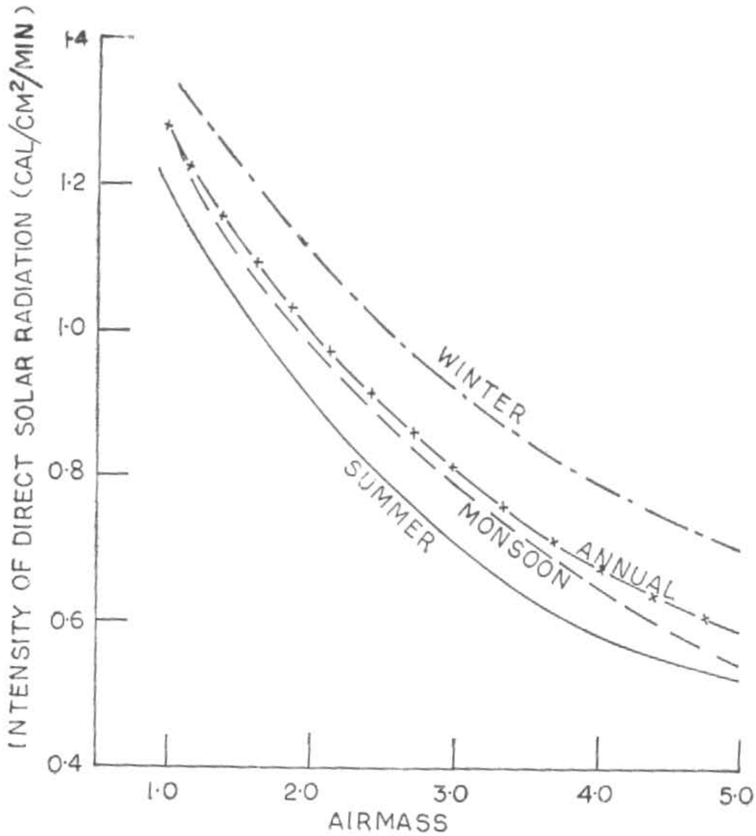

Fig. 1(a). Seasonal variation of intensity with air mass — Poona (1958-1962)

β is the Ångström turbidity coefficient and α a factor which varies from 0 to 4 and has a reasonable average value of 1·3. β is computed from observed values of I_k and is a measure of the aerosol content of the atmosphere. It, however, depends partially and in varying degrees on the water vapour content.

3. Results

3.1. *Intensity of solar radiation* — Regular measurements four times a day of I_t, the direct solar radiation for the entire spectrum and with various filters of I_G , I_R and I_S; at two representative stations in north and Peninsular India (Delhi 28° 35′ N, 77° 13′ E and Poona 18° 32′ N, 73° 51′ E), are available for over 7 years. The mean values of I_t for five years 1958—62 for the main seasons, winter (October—February), summer (March—June) and monsoon (July—September) are presented in Figs. 1(a) and 1 (b) and Tables 1(a) and 1(b). Mean monthly values of the intensity of solar radiation year by year for Poona and Delhi are given in Tables 1(c) and 1(d).

The intensity of radiation at both stations are highest during winter and least during summer, for the same optical air masses and solar elevations; the ratio of maximum to minimum is about 1·3 for Poona and 1·2 for

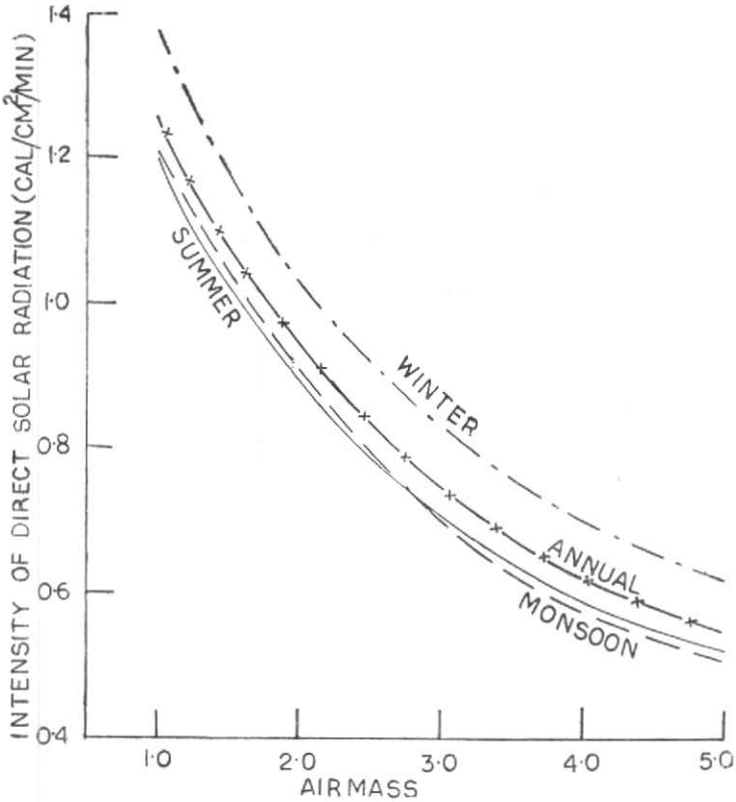

Fig. 1(b). Seasonal variation of intensity with air mass — Delhi (1958–1962)

TABLE 1(a)

Mean values of intensity (cal/cm²/min) for specified air masses during 1958—1962 (Poona)

Air mass	Summer	Monsoon	Winter	Annual
0·96	1·205	1·313	1·360	1·293
1·00	1·185	1·267	1·350	1·267
1·50	1·035	1·097	1·227	1·120
2·00	0·905	0·980	1·108	0·998
2·50	0·795	0·880	1·008	0·894
3·00	0·708	0·800	0·918	0·809
3·50	0·638	0·722	0·847	0·736
4·00	0·587	0·648	0·788	0·674
4·50	0·547	0·590	0·745	0·627
5·00	0·522	0·542	0·703	0·589

TABLE 1(b)

Mean values of intensity (cal/cm²/min) for specified air masses during 1958—1962 (New Delhi)

Air mass	Summer	Monsoon	Winter	Annual
1·00	1·205	1·218	1·380	1·268
1·50	1·025	1·038	1·185	1·083
2·00	0·896	0·908	1·033	0·946
2·50	0·788	0·798	0·923	0·836
3·00	0·708	0·697	0·830	0·745
3·50	0·643	0·623	0·764	0·677
4·00	0·590	0·570	0·703	0·621
4·50	0·550	0·538	0·668	0·585
5·00	0·523	0·507	0·617	0·549

TABLE 1(c)

Mean values of direct solar radiation (cal/cm²/min) at Poona

	1958	1959	1960	1961	1962	Mean	1958	1959	1960	1961	1962	Mean
			0830 IST						1130 IST			
Jan	0·853	0·876	0·853	0·858	0·940	0·876	1·323	1·305	1·284	1·320	1·353	1·317
Feb	1·010	0·907	0·889	0·982	0·901	0·938	1·345	1·327	1·310	1·390	1·329	1·340
Mar	0·947	0·889	0·987	0·891	0·955	0·934	1·336	1·273	1·317	1·282	1·241	1·290
Apr	0·997	0·977	0·889	1·016	0·960	0·968	1·267	1·239	1·206	1·264	1·224	1·240
May	0·953	0·961	0·960	—	1·037	0·990	1·152	1·241	1·211	1·245	1·221	1·214
Jun	1·041	—	—	—	—	1·041	1·205	1·106	—	—	—	1·155
Jul	—	—	—	—	—	—	—	—	—	—	—	—
Aug	—	—	—	—	—	—	—	—	—	—	—	—
Sep	0·936	—	—	—	—	0·936	—	—	—	—	—	—
Oct	1·073	1·077	1·152	1·049	0·987	1·068	1·328	1·351	1·415	1·326	1·233	1·331
Nov	1·052	1·040	0·985	1·004	1·050	1·026	1·346	1·394	1·357	1·333	1·353	1·357
Dec	0·935	0·959	0·949	1·001	1·024	0·976	1·328	1·354	1·348	1·337	1·311	1·336
			1430 IST						1730 IST			
Jan	1·306	1·306	1·279	1·309	1·314	1·303	0·589	0·740	0·774	0·730	0·751	0·717
Feb	1·392	1·299	1·287	1·369	1·331	1·336	0·768	0·762	0·720	0·832	0·863	0·789
Mar	1·219	1·218	1·304	1·234	1·341	1·263	0·634	0·651	0·772	0·739	0·792	0·718
Apr	1·181	1·205	1·118	1·212	1·159	1·175	0·597	0·604	0·605	0·702	0·592	0·620
May	1·091	1·136	—	—	1·144	1·124	0·621	0·678	0·726	—	0·638	0·646
Jun	1·167	—	—	—	—	1·167	0·802	—	—	—	—	0·802
Jul	—	—	—	—	—	—	—	—	—	—	—	—
Aug	—	—	—	—	—	—	—	—	—	—	—	—
Sep	—	—	—	—	—	—	—	—	—	—	—	—
Oct	1·286	1·289	1·339	1·279	1·167	1·272	0·734	0·708	—	0·775	0·539	0·689
Nov	1·288	1·296	1·310	1·275	1·297	1·293	0·925	0·791	0·653	0·657	0·705	0·746
Dec	1·277	1·303	1·297	1·291	1·307	1·295	0·740	0·767	0·712	0·670	0·719	0·722

TABLE 1(d)

Mean values of direct solar radiation (cal/cm²/min) at New Delhi

	1958	1959	1960	1961	1962	Mean	1958	1959	1960	1961	1962	Mean
				0830 IST						1130 IST		
Jan	0·675	0·740	0·765	0·736	0·712	0·726	1·153	1·275	1·213	1·217	1·148	1·201
Feb	0·922	1·022	0·831	1·019	0·655	0·890	1·260	1·338	1·275	1·243	1·092	1·242
Mar	0·887	0·971	0·922	0·994	0·791	0·913	1·207	1·292	1·251	1·185	1·161	1·219
Apr	0·854	1·005	1·034	1·049	0·773	0·951	1·076	1·231	1·213	1·249	1·104	1·175
May	0·904	0·935	0·986	0·794	0·759	0·876	1·216	1·141	1·121	1·056	1·078	1·122
Jun	0·674	0·808	0·766	—	0·688	0·734	—	0·960	0·962	—	—	0·961
Jul	—	0·991	—	—	—	0·991	—	1·192	—	—	—	1·192
Aug	0·782	1·104	—	—	—	0·943	1·224	1·268	—	—	—	1·246
Sep	—	1·015	0·825	0·810	0·706	0·839	—	1 237	1·081	1·072	1·047	1·109
Oct	0·664	0·923	0·911	0·787	0·708	0·799	1·282	1·242	1·197	1·074	1·034	1·166
Nov	0·982	1·021	0·812	0·710	0·828	0·871	1·319	1·310	1·234	1·112	1 197	1·234
Dec	0·738	0·823	0·752	0·683	0·708	0·741	1·290	1·269	1·177	1·088	1·118	1·188
				1430 IST						1730 IST		
Jan	1·112	1·280	1·221	1·200	1·086	1·182	—	—	—	—	—	—
Feb	1·202	1·289	1·194	1·151	1·132	1·194	0·569	0·640	0·492	—	—	0·567
Mar	1·178	1·268	1·208	1·173	1·192	1·204	0·543	0·767	0·668	0·645	0·704	0·665
Apr	1·066	1·134	1·187	1·206	1·018	1·122	0·559	0·595	0·581	0·658	0·567	0·592
May	1·075	1·163	1·067	1·008	1·049	1·072	—	0·729	0·583	0·618	0·664	0·649
Jun	—	—	—	—	—	—	—	—	—	—	—	—
Jul	—	—	—	—	—	—	—	—	—	—	—	—
Aug	—	—	—	—	—	—	—	—	—	—	—	—
Sep	—	—	1·063	—	—	1·063	—	—	—	0·634	—	0 634
Oct	1·210	1·096	1·142	1·013	0·990	1·090	—	0·579	0·897	0·172	0·337	0·496
Nov	1·214	1·217	1·100	1·019	1·107	1·131	—	—	—	—	—	—
Dec	1·125	1·207	1·085	0·976	1·049	1·088	—	—	—	—	—	—

Delhi. The values of intensity on clear days during the monsoon at both stations are about the same or slightly more than those during summer. The reduced values of intensity during the summer months are to be ascribed to scattering and absorption by dust — a familiar feature over India during the hot, dry pre-monsoon months. During the monsoon, the dust content is reduced by precipitation but the increased water vapour content causes a reduction in the intensity of direct solar radiation. All observations refer only to cloudless days. The number of observations during the monsoon is naturally very few and the mean values given may not be representative of actual conditions.

No large variations in intensity are observed at Poona from year to year unlike Delhi, where very large fluctuations are present. On the whole intensities at Poona are higher than at Delhi throughout the year. This is to be expected, since Poona is at a higher elevation and Delhi borders the arid zones of northwest India.

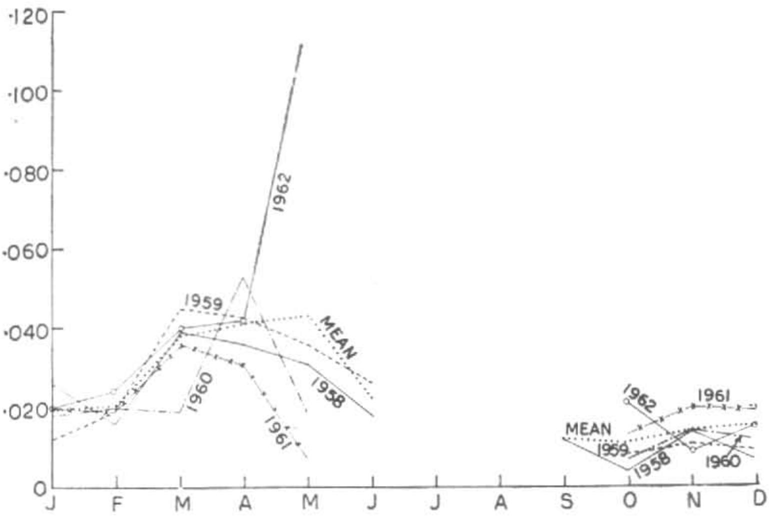

Fig. 2(a). Annual march of turbidity coefficient β — Poona

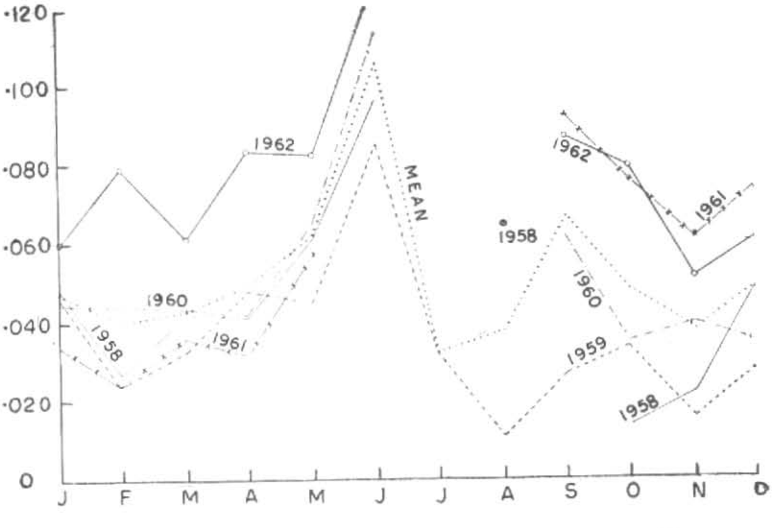

Fig. 2(b). Annual march of turbidity coefficient β — New Delhi

3.2. *Atmospheric turbidity* — Values of Ångström's turbidity coefficient β for the hours of observations 0830, 1130, 1430 and 1730 IST have been computed from equation (1). Mean values of β for the years 1958—62 for the different hours are given in Tables 2(a) and 2(b) for Poona and Delhi. Mean monthly and seasonal values of β year by year are given in Tables 3(a), 3(b), 3(c) and 3(d). The annual march of β for the different years is illustrated in Figs. 2(a) and 2(b).

TABLE 2(a)

Mean values of turbidity coefficient β at Poona

	1958	1959	1960	1961	1962	Mean	1958	1959	1960	1961	1962	Mean
			0830 IST						1130 IST			
Jan	·045	·031	·036	·046	·034	·038	·016	·008	·016	·008	·014	·012
Feb	·032	·032	·036	·034	·038	·034	·016	·010	·009	·016	·021	·014
Mar	·056	·061	·031	·053	·042	·049	·024	·028	·010	·022	·042	·025
Apr	·059	·049	·061	·031	·041	·048	·026	·030	·034	·017	·021	·026
May	·029	·044	·029	—	·022	·031	·019	·027	·009	·007	·014	·015
Jun	·021	—	—	—	—	·021	·009	·026	—	—	—	·017
Jul	—	—	—	—	—	—	—	—	—	—	—	—
Aug	—	—	—	—	—	—	—	—	—	—	—	—
Sep	·012	—	—	—	—	·012	—	—	—	—	—	—
Oct	·007	·021	·024	·031	·025	·022	—	·009	—	·010	·019	·013
Nov	·029	·026	·033	·041	·026	·031	·006	·002	·004	·013	·003	·006
Dec	·021	·027	·030	·029	·028	·027	·004	·006	·002	·020	·020	·010
			1430 IST						1730 IST			
Jan	·010	·002	·008	·005	·019	·009	·035	·008	·011	·020	·018	·018
Feb	·003	·010	·009	·007	·007	·007	·014	·023	·027	·020	·030	·023
Mar	·034	·038	·006	·025	·032	·027	·043	·053	·031	·052	·045	·045
Apr	·024	·038	·051	·023	·038	·035	·036	·057	·068	·055	·069	·042
May	·034	·035	—	—	·037	·035	·041	·037	—	—	·050	·043
Jun	·015	—	—	—	—	·015	·028	—	—	—	—	·028
Jul	—	—	—	—	—	—	—	—	—	—	—	—
Aug	—	—	—	—	—	—	—	—	—	—	—	—
Sep	—	—	—	—	—	—	—	—	—	—	—	—
Oct	·004	·001	·002	·007	·023	·007	·006	·001	—	·006	·019	·008
Nov	·008	·006	·005	·007	·003	·006	·015	·008	·013	·020	·003	·014
Dec	·001	·002	·007	·009	·005	·005	·002	·002	·010	·017	·009	·008

The turbidity coefficient β at Poona is a maximum (·068) during the summer months March—May and a minimum (·012) during the monsoon months. No large variations in β are observed from year to year. The highest mean turbidity observed was 0·123 in 1962. 1962 was the most turbid of all the five years and 1961 the least. The fall in turbidity in June is associated with the onset of the monsoon over Poona.

The turbidity coefficient β at Delhi is a maximum (0·088) during the summer and a minimum during the monsoon (0·023). Unlike Poona where the highest value of β is recorded in March or April, it occurs in

TABLE 2(b)

Mean values of turbidity coefficient β at New Delhi

	1958	1959	1960	1961	1962	Mean	1958	1959	1960	1961	1962	Mean
			0830 IST						1130 IST			
Jan	·073	·080	·064	·059	·062	·068	·035	·035	·043	·023	·058	·039
Feb	·041	·034	·051	·031	·096	·051	·022	·024	·037	·022	·075	·036
Mar	·062	·044	·058	·027	·094	·057	·043	·044	·035	·042	·060	·045
Apr	·071	·050	·039	·030	·093	·055	·058	·039	·042	·041	·084	·053
May	·076	·054	·065	·060	·110	·073	·039	·053	·068	·055	·069	·057
Jun	·096	·086	·110	—	·127	·105	—	·083	·115	—	—	·099
Jul	—	·040	—	—	—	·040	—	·024	—	—	—	·024
Aug	·085	·009	—	—	—	·047	·046	·014	—	—	—	·030
Sep	—	·024	·052	·076	·096	·062	—	·030	·039	·077	·078	·056
Oct	·030	·049	·051	·066	·108	·061	·009	·029	·044	·063	·084	·046
Nov	·032	·017	·054	·067	·048	·034	·016	·019	·032	·059	·036	·032
Dec	·074	·043	·037	·084	·060	·060	·023	·018	·032	·066	·072	·042
			1430 IST						1730 IST			
Jan	·036	·024	·029	·021	·060	·032	—	—	—	—	—	—
Feb	·025	·026	·051	·019	·065	·037	·019	·013	·036	—	—	·023
Mar	·030	·027	·046	·043	·044	·038	·031	·015	·031	·033	·037	·029
Apr	·015	·046	·035	·021	·082	·040	·018	·057	·051	·036	·071	·047
May	·067	·032	·056	·055	·083	·059	—	·039	·073	·056	·066	·059
Jun	—	—	—	—	—	—	—	—	—	—	—	—
Jul	—	—	—	—	—	—	—	—	—	—	—	—
Aug	—	—	—	—	—	—	—	—	—	—	—	—
Sep	—	—	·033	—	—	·033	—	—	—	·031	—	·031
Oct	·002	·035	·027	·064	·066	·039	—	·023	·017	·111	·056	·052
Nov	·018	·013	·034	·058	·040	·033	—	—	—	—	—	—
Dec	·049	·022	·037	·073	·051	·046	—	—	—	—	—	—

June, in Delhi due to the later onset of monsoon at Delhi. The monsoon observations are too few to be representative but gives a mean value of about 0·066. Turbidity over Delhi is twice that for Poona during summer and about 5 times during the monsoon. The annual variations are very large even for the mean monthly values, ranging from ·014 to ·127. The variations from year to year, unlike those over Poona, are also very large. The maxima also shift from year to year with the time of onset of the monsoon. 1962 was more turbid throughout the year.

The mean values of the turbidity coefficients obtained for the three main seasons and synoptic airmasses for Poona and Delhi are given below —

		Poona	Delhi
Winter	P_c	·016	·044
Summer	T_c	·038	·062
Monsoon	E_m	·012	·066

Measurements of diffuse radiation (Mani and Chacko 1963b) at Poona and Delhi support the above observations. Diffuse radiation is a maximum during the summer and least during winter, the ratio of diffuse to total solar radiation on clear days being 32 per cent in summer and 12 per cent during winter for Delhi. On clear days D/T is mainly a function of turbidity and water vapour content. The increased pollution and the result of increased convective effect which disperse dust and water vapour in the atmosphere account for the higher values of D/T in summer at both stations. The ratio D/T was smaller for Poona, indicating the atmosphere over Delhi to be less transparent.

3.3. *Transmission coefficient* — The mean transmission coefficient q computed from the relation $I = I_0\ q^m$ for the different months, four times during the day, 0830, 1130, 1430 and 1730 IST for the period 1958—1962 for the stations Poona and Delhi are given in Tables 4(a) and 4(b) and illustrated in Figs. 3(a) and 3(b). The atmosphere is more transparent during the winter and monsoon months and the transmission coefficients for Poona are generally higher than those for Delhi. Considering the mean q for the whole day, Poona has the highest value in December 0·77 and lowest in June 0·64. The highest and lowest values for Delhi are 0·76 in January and 0·55 in June. This is in conformity with the conclusions arrived at in the earlier paragraphs.

Another interesting observation is that the atmosphere is more transparent at 0830 and 1730 IST than at 1130 and 1430 IST throughout the year at both stations. The values of q are the highest in the evening and least at noon. This may be ascribed to increased convection and turbulent mixing during the day and stratification of the layers near the ground during the night and early morning.

4. Discussion

Measurements of the various spectral components of incoming shortwave solar radiation show a maximum attenuation in solar radiation during the dry summer months over north and central India. A tropical continental air mass lies over western, central and north India during this season. This is the driest and hottest air over India, with marked instability, intense insolation and turbulence leading to the development of dust raising winds and duststorms, which persist for days reducing visibility to a few km. The increased pollution and the result of increased convective effect which disperses dust and water vapour in the atmosphere account for the higher values of β at both stations during summer. The dense dust layer is known to extend to over 10 km in the atmosphere and to play an important part in the radiation balance and in the circulation over India. The values of β in the T_c air mass over Poona and Delhi are 0·038 and 0·062 respectively. Ångström (1930) had given β as 0·07 to 0·12 for T_m and 0·10 to 0·20 for T_c.

During winter the modified cold air over north and central India is of continental polar origin characterised by convective stability, clear skies and good visibility. The mean values of β obtained are 0·016 for Poona and 0·044 for Delhi.

Cool, highly humid and convectively indifferent equatorial maritime air lies over south and central India, during the monsoon, characterized by cloudy to overcast skies and frequent rain or drizzle. The turbidity coefficient is the lowest and the air is clearest after the monsoon after the cleansing by precipitation of the atmosphere of its dust content. In the north, this air mass becomes modified as it turns west round the seasonal trough to the north. The mean values of β for Poona and Delhi are 0·012 and 0·066 respectively.

TABLE 3

Mean values of Ångström turbidity coefficient β

	1958	1959	1960	1961	1962	Mean	1958	1959	1960	1961	1962	Mean
			(a) POONA						(b) NEW DELHI			
Jan	·026	·012	·018	·020	·020	·019	·048	·046	·045	·034	·060	·047
Feb	·016	·019	·020	·019	·024	·020	·027	·024	·044	·024	·079	·040
Mar	·039	·045	·019	·038	·040	·038	·042	·033	·043	·036	·061	·043
Apr	·036	·043	·053	·031	·042	·041	·041	·048	·042	·032	·083	·049
May	·031	·036	·019	·007	·123	·043	·061	·045	·065	·057	·082	·062
Jun	·018	·026	—	—	—	·022	·096	·085	·113	—	·127	·105
Jul	—	—	—	—	—	—	—	·032	—	—	—	·032
Aug	—	—	—	—	—	—	·065	·011	—	—	—	·038
Sep	·012	—	—	—	—	·012	—	·027	·062	·092	·087	·067
Oct	·006	·008	·007	·013	·021	·011	·014	·034	·035	·076	·079	·048
Nov	·014	·011	·014	·020	·009	·014	·022	·016	·040	·061	·051	·038
Dec	·007	·009	·012	·019	·015	·015	·049	·028	·035	·074	·061	·049
Mean	·020	·023	·020	·020	·037		·047	·036	·052	·054	·077	
						Seasonal values of β						
			(c) POONA						(d) NEW DELHI			
Winter	·014	·012	·016	·018	·018	·016	·032	·030	·040	·054	·066	·044
Summer	·031	·037	·030	·025	·068	·038	·060	·053	·066	·042	·088	·062
Monsoon	·012	—	—	—	—	·012	·065	·023	·062	·092	·087	·066

TABLE 4

Mean values of transmission coefficients during 1958—62

	0830 IST	1130 IST	1430 IST	1730 IST	Mean	0830 IST	1130 IST	1430 IST	1730 IST	Mean
		(a) POONA					(b) NEW DELHI			
Jan	·77	·72	·74	·80	·76	·79	·73	·75	—	·76
Feb	·76	·70	·71	·78	·74	·78	·70	·70	·79	·74
Mar	·72	·66	·68	·73	·70	·72	·66	·68	·76	·71
Apr	·68	·62	·63	·68	·65	·68	·62	·62	·69	·65
May	·67	·61	·63	·69	·65	·62	·58	·59	·66	·61
Jun	·70	·59	·60	·67	·64	·59	·51	—	—	·55
Jul	—	—	—	—	—	·65	·58	—	—	·61
Aug	—	—	—	—	—	·68	·66	—	—	·67
Sep	·67	—	—	—	·67	·67	·61	·64	·75	·67
Oct	·73	·69	·71	·81	·73	·68	·65	·68	·75	·69
Nov	·75	·72	·74	·82	·76	·75	·71	·72	—	·72
Dec	·77	·72	·74	·83	·77	·78	·72	·72	—	·73

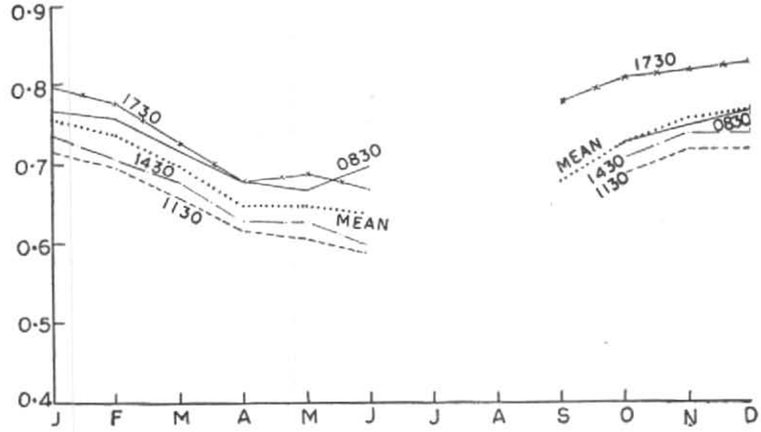

Fig. 3.(a). Annual march of transmission coefficient — Poona

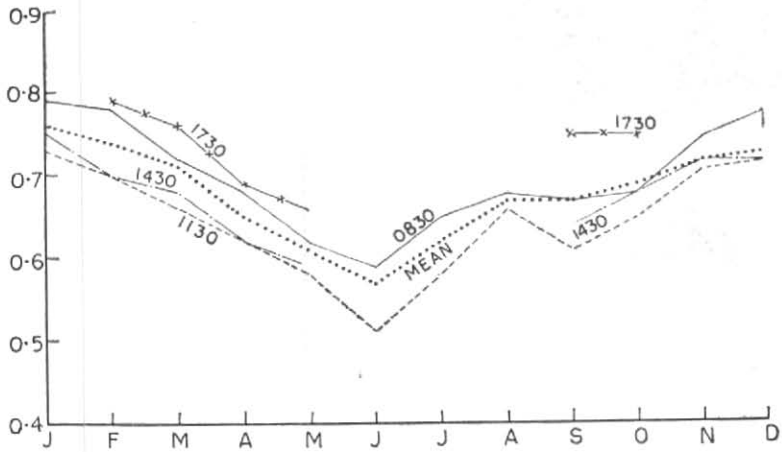

Fig. 3 (b). Annual march of transmission coefficient—New Delhi

5. Conclusion

The main results may now be summarised :

1. Attenuation of direct solar radiation and atmospheric turbidity are a maximum during the dry, dusty summer months in both central and north India and a minimum during the monsoon months and after, when the atmosphere has been cleansed of its dust content by precipitation.

2. The turbidity at Delhi is two to five times that over Poona throughout the year as a result of Delhi's proximity to the arid regions to the northwest and the increased elevation of Poona above sea level. The variations from year to year are also much more pronounced at Delhi.

3. The sudden fall in turbidity during June—July at both stations is associated

with the onset of the monsoon in the two areas.

4. The intensity of direct solar radiation is a maximum during winter at both stations and a minimum during the dry summer months, for the same optical air masses and solar elevations. During the dry seasons the intensity is reduced by absorption and scattering by dust and during monsoon by water vapour.

5. Atmospheric transmissivity is more during the winter and monsoon months than during the summer and more during the morning and evening than during the day.

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