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Reaction of radiometric parameters to atmospheric pollution : Part II — A comparative study between pairs of stations

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सार—प्रस्तुत शोध अध्ययन के प्रथम भाग में, एक निश्चित स्थान पर, समय के साथ होने वाले वायुमंडलीय प्रदूषण के प्रभाव पर चर्चा की गई थी। किसी स्थान पर उत्पन्न होने वाला कणीय पदार्थ आस-पास के क्षेत्रों पर फैल जाता है। अत: कुछ केन्द्रों के मध्य तुलनात्मक अध्ययन का विशेष महत्व है। जोधपुर की तुलना में नई दिल्ली में प्रौद्योगिक गतिविधि का प्रभाव स्पष्ट रूप से दिखाई देता है। यद्यपि अहमदाबाद और कलकत्ता जैसे पूर्व विकसित क्षेत्रों में उल्लेखनीय परिवर्तन नहीं पाए गए हैं। लगभग सभी केन्द्रों पर पृथ्वी से निकलने वाली वास्तविक विकिरणी ऊर्जा में कमी के लक्षण दिखाई देते हैं।

ABSTRACT. In part I, the effect of atmospheric pollution over time at a given location was discussed. The particulate matter generated over a place is dispersed to surrounding areas. Thus a comparative study between pairs of stations is worthwhile. The effect of industrial activity is clearly seen in the case of New Delhi when compared to Jodhpur. However, the changes are not highly significant in the case of the already developed areas like Ahmedabad and Calcutta. Almost all stations show a decreasing trend in the net outgoing terrestrial radiant energy.

1. Introduction

To highlight the effect of human interference with the environment by way of developmental activities in the fields of both agriculture and industries and the consequent urbanisation and the ever increasing population, the stations considered in part I are paired here in such a way that one station is affected more than the other with which it is compared. A mere presentation of comparative data itself is revealing. Mani *et al.* (1973) made such studies in a limited way. To keep the discussions brief, only two blocks 1970-71 and 1985-86, common to all stations are considered and the analysis presented here.

1.1. *Comparison between Jodhpur and Delhi*

Jodhpur (26.3°N) and Delhi (28.6°N) are both located in the same subtropical latitudinal belt and subjected to the heavy injection of dust load of the subtropics carried over from the deserts in the west. Both are affected by the winter rains caused by the eastward moving extratropical disturbances that cause large fluctuations in the irradiances depending upon their relative strength of activities at different times. Jodhpur is affected more by the deserts due to its proximity, and has serveral small scale industrial units but mostly located east of the radiation station. Delhi has more industrial units and a higher level of urbanisation and is, therefore, subjected to greater environmental stresses.

1.1.1. Fig. 1 gives the comparative values of the different radiometric quantities studied, *viz.*, H_g, H_d, S, β and $E_l^{*}\uparrow$ Global radiant exposure H_g at Delhi was consistently lower than that at Jodhpur by at least 6 per cent and it was lower than 10 per cent or more during the post-monsoon period. During this period Delhi 1970-71, measurements were being made from the Lodhi Complex. 1985-86 picture is different, Delhi records slightly higher irradiance levels than Jodhpur. H_g at Delhi is substantially lower only in December to February period. This may, perhaps, be attributed to the dry conditions that prevailed over Jodhpur during 1985-86 (26 per cent less rainfall — Table 1 of part I).

Though H_g was recording in different ways during the two periods, diffuse radiant exposure H_d is always more at Delhi. It was about 28 per cent more than Jodhpur during 1970-71 and about 13 per cent during 1985-86. The build up of the dust load over the period, January to April has been rather slow during 1970-71 as compared to 1985-86. The percentage difference is uniformly higher in all the months during 1985-86 as compared to 1970-72.

1.1.2. The direct solar irradiance S was consistently much lower at Delhi during 1970-71. It is lower in 1985-86 but the order of difference is less. On an average, Delhi had remained consistently lower by about 7 per cent during both the periods, the drop in S in the individual stations during the period were also almost by the same percentage, 17-18 per

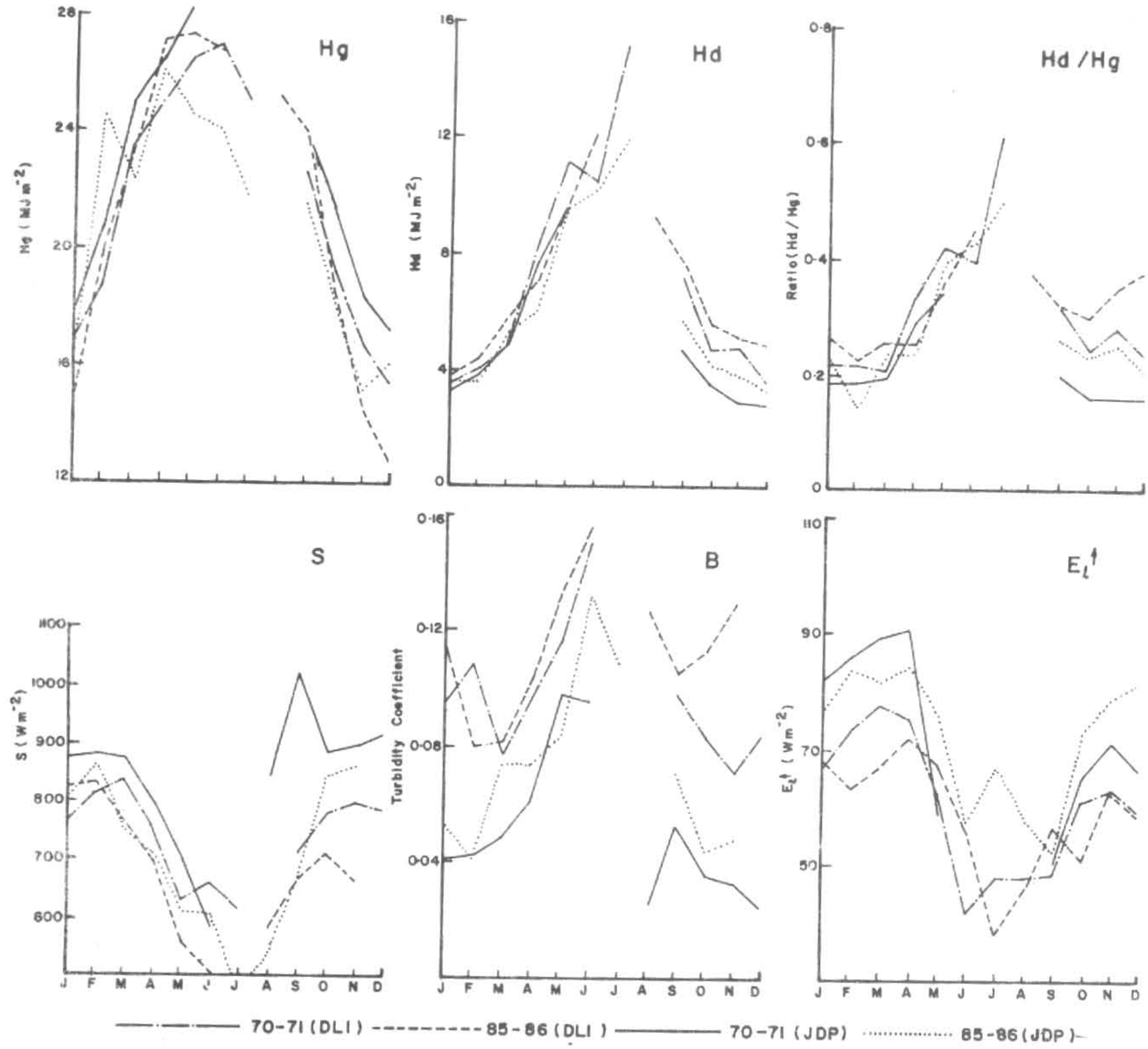

Fig. 1. Radiometric quantities at Jodhpur and New Delhi

cent. The annual values of S over Jodhpur and Delhi are 843 Wm^{-2} and 781 Wm^{-2} respectively during 1970-71. These have reduced to 727 Wm^{-2} and 679 Wm^{-2} respectively by 1985-86. The turbidity coefficient β, however, gives a different picture. The value of β has increased by over 60 per cent at Jodhpur during the 15-year period from 1970-71 while it is about 12 per cent increase over Delhi. The change of site at Delhi has some contribution to make. The large differences in the values of β seen between the two stations in 1970-71 has decreased in 1985-86, though the differences between the two stations are still considerable. The difference was as high as 44 per cent in April during 1970-71 whereas it is only 11 per cent but in February during 1985-86.

1.1.3. The net outgoing terrestrial radiant energy $E_l^*\uparrow$ is equally affected by the atmospheric pollutants by way of absorption and re-radiation to the earth. In addition to the pollutants, the higher moisture content in the air over Delhi contributes more to the downward radiation as compared to that over Jodhpur. The annual picture gives a somewhat same percentage difference between the two station — about 18 to 19 per cent Jodhpur losing more. 1985-86 shows that the percentage is more uniform throughout the year as compared to 1970-71.

1.1.4. Fig. 2 shows these variations in different parameters in a more apparent way. The higher pollution content is more evident from the high ratios in β

TABLE 1

Percentage differences between pairs of stations

		Winter					Pre-monsoon					Post-monsoon				
		S	H_g	H_d	β	$E_l^{*}\uparrow$	S	H_g	H_d	β	$E_l^{*}\uparrow$	S	H_g	H_d	β	$E_l^{*}\uparrow$
Jodhpur and	1970-71	−12	−9	+14	+123	−17	−7	−6	+8	+54	−10	−11	−10	+49	+121	−10
New Delhi	1985-86	−2	−17	+26	+106	−21	−3	−7	+9	+37	−14	−20	0	+35	+166	−17
Bhavnagar and	1970-71	−3	+5	+1	−10	—	−7	0	−3	0	—	−1	+20	−1	−1	—
Ahmedabad	1985-86	−5	−5	−2	+5	—	−6	−10	+15	−9	—	−6	+4	+16	+14	—
Nagpur and	1970-71	+13	+3	−12	−52	+7	+20	+2	+14	−63	+7	+20	+1	+9	+20	+10
Pune	1985-86	+5	+2	−16	−22	−25	+7	−1	−22	−37	−60	+11	−11	−12	+11	−13
Ahmedabad and	1970-71	−17	−7	+49	+197	−27	−4	+1	+24	+53	−34	−10	−1	+28	−10	−25
Calcutta	1985-86	−30	−3	+35	+122	−2	−27	0	+10	+77	+10	−29	−14	+4	−29	+9

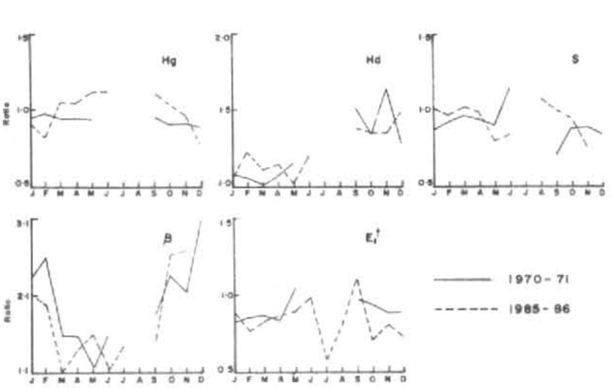

Fig. 2. Ratio of radiometric parameters at New Delhi and Jodhpur

and much smaller fractional values in $E_l^{*}\uparrow$. That Jodhpur also has higher pollutants over the decade and a half is also obvious when we find that the ratios of almost all parameters do not much change over the period.

1.1.5. Table 1 gives the seasonal percentage differences in radiation parameters at the stations. The nearly same trends in rainfall quantities during the pre-monsoon periods (*see* Table 2) has kept the differences in the radiation parameter very small and nearly the same both during 1970-71 and 1985-86 blocks. The rainfall deficits during the 1985-86 block have ensured more variation in the sky conditions and hence higher percentage for Delhi over that for Jodhpur.

1.2. *Comparison between Bhavnagar and Ahmedabad*

As mentioned in part I, Bhavnagar (21.75°N) is on the coastline with plenty of salt extracting farms, while Ahmedabad (23.07°N) is continental in its weather. Ahmedabad with its early industrialisation has a highly polluted air. Bhavnagar on the other hand has little of the heavy industries but has the marine salt hygroscopic particles with plenty of moisture brought in by the sea breeze.

1.2.1. The global radiant exposure H_g does not show any serious difference at the two places during the January-May period during 1970-71 (Fig. 3). But Ahmedabad surprisingly reads higher during the post-monsoon months during this block. It is as high as 18-20 per cent. On an average Ahmedabad was receiving a marginally higher irradiance on clear days. This picture, however, gets reversed during 1985-86 with Bhavnagar receiving marginally higher irradiance. The period January to May has consistently low irradiance over Ahmedabad than that over Bhavnagar. The post-monsoon difference is very much reduced and Ahmedabad has only about 7 per cent higher irradiance.

1.2.2. Unlike H_g, H_d is generally lower over Bhavnagar during 1970-71. 1985-86 block shows sharp increase in H_d at Ahmedabad. The nearly same average values of 1970-71 at Ahmedabad and Bhavnagar are no more seen during 1985-86. Ahmedabad receives an 11 per cent excess diffuse irradiance than Bhavnagar. The pre-monsoon period has more than 20 per cent of H_d at Ahmedabad. However, both places have responded in a similar way by having a higher irradiance level for H_d during September in 1985-86

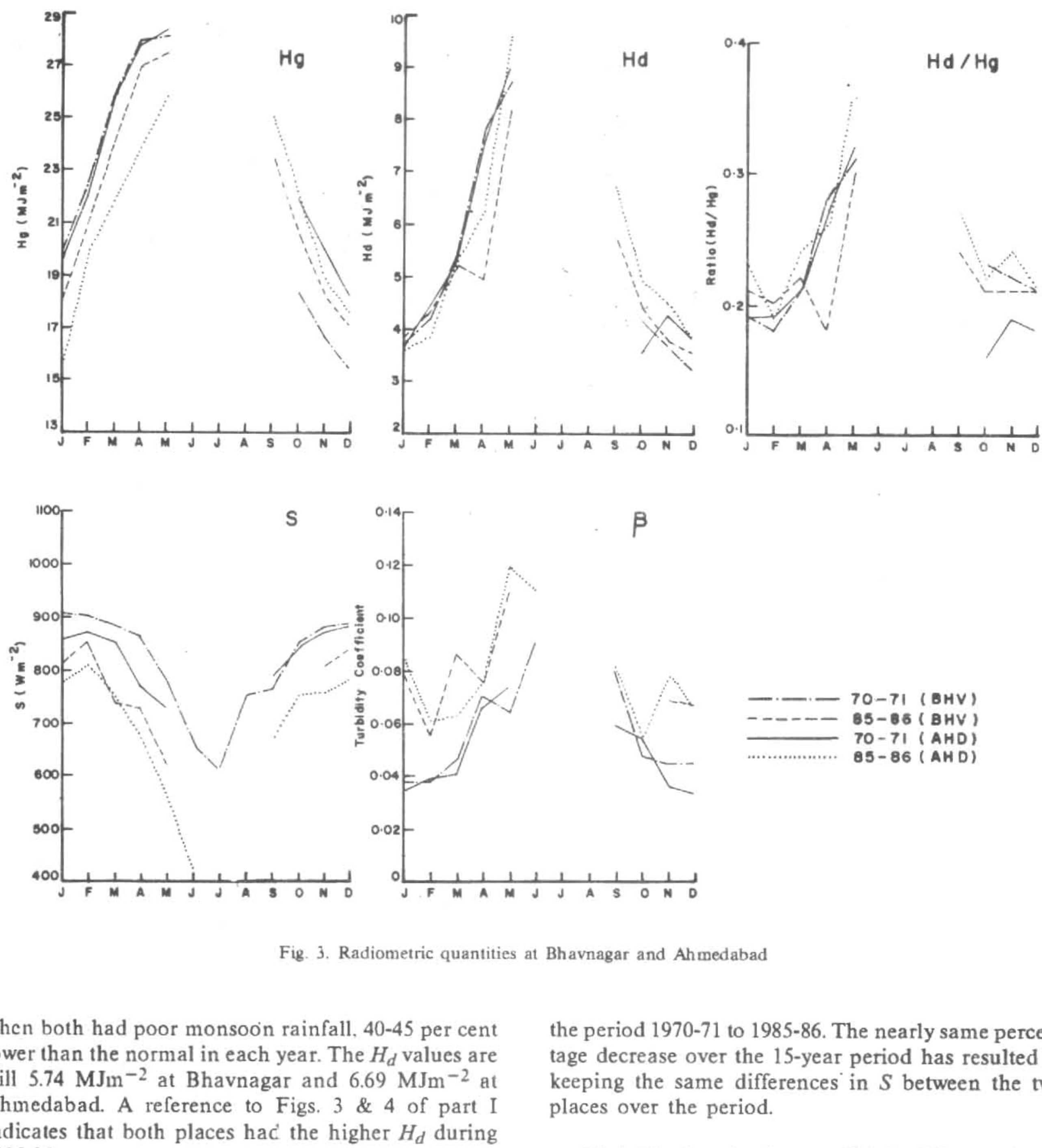

Fig. 3. Radiometric quantities at Bhavnagar and Ahmedabad

when both had poor monsoon rainfall, 40-45 per cent lower than the normal in each year. The H_d values are still 5.74 MJm^{-2} at Bhavnagar and 6.69 MJm^{-2} at Ahmedabad. A reference to Figs. 3 & 4 of part I indicates that both places had the higher H_d during 1985-86.

1.2.3. Fig. 2 shows clearly the atmospheric conditions that existed during 1970-71 and 1985-86. Ahmedabad was receiving a slightly lower (3 per cent) direct solar irradiance S during 1970-71. The differences were predictably of higher order at Ahmedabad during April-May. Fig. 3 of part I indicates that S has decreased by 13 per cent over Ahmedabad. Bhavnagar (Fig. 4 of part I) had a reduction of 11 per cent during the period 1970-71 to 1985-86. The nearly same percentage decrease over the 15-year period has resulted in keeping the same differences in S between the two places over the period.

1.2.4. Fig. 2 again shows a slightly different picture in the case of variations of β. From the values of β Ahmedabad appears to be more transparent in the 1970-71 block. A check on the rainfall data shows that Ahmedabad had a mere 49 mm annual rain in 1970 and 544 mm in 1971 as against the normal 823 mm. On the other hand Bhavnagar had 1460 mm in 1970 and 534 mm during 1971 as against its annual normal of 661 mm. The obvious inference is that the presence of copious moisture at Bhavnagar with the hygroscopic

TABLE 2

Seasonal rainfall in percentage during the two blocks

	Winter	Pre-monsoon	Monsoon	Post-monsoon	Winter	Pre-monsoon	Monsoon	Post-monsoon
			Jodhpur				**New Delhi**	
1970	−100	0.0	+50	−100	+47	+123	+5	−74
1971	−100	+571	−24	−59	−44	+98	+33	−76
1985	−100	+939	−67	−34	−85	−55	−3	+152
1986	−71	+542	−37	−72	+129	+66	−67	−100
			Ahmedabad				**Bhavnagar**	
1970	−80	−100	−94	−95	−63	+65	+136	−100
1971	−100	+86	−35	−33	−100	−77	−11	−98
1985	−100	+163	−38	+129	−100	−99	−40	+188
1986	−100	+42	−45	−100	−100	−100	−47	−100
			Pune				**Nagpur**	
1970	−100	−5	−36	−16	+1	+43	+44	−98
1971	−100	−46	−21	−67	+198	+23	−10	+50
1985	−100	−63	−33	+21	+54	−44	−10	+417
1986	−100	−42	−5	−98	+431	−50	−19	−68
			Calcutta					
1970	−74	−29	−2	+55				
1971	+148	+74	+39	+50				
1985	−64	−46	+6	−18				
1986	−44	−5	+47	+79				

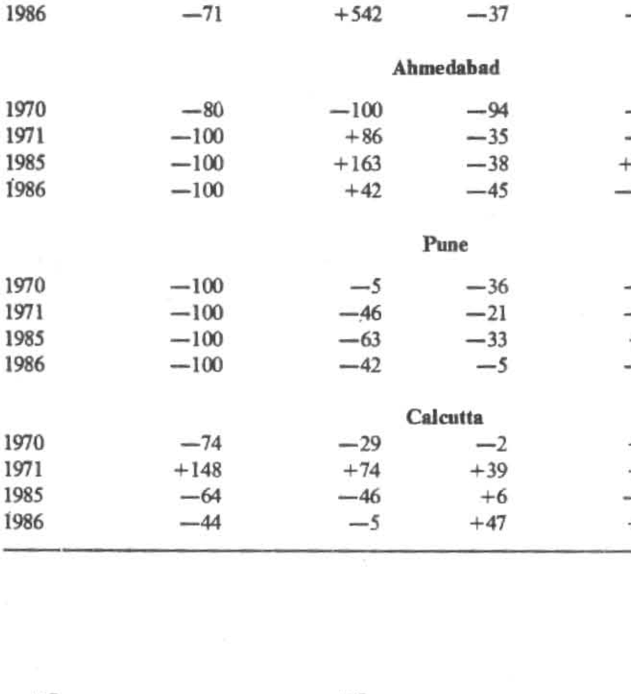

Fig. 4. Ratio of radiometric parameters at Ahmedabad and Bhavnagar

nuclei available nearby has caused the transparency of the atmosphere to decrease. The period 1985-86 shows that Ahmedabad had a marginal annual rainfall surplus of 7 per cent in 1985 and a large 46 per cent deficit in 1986 whereas it was, in the case of Bhavnagar, 27 per cent deficit in 1985 and 52 per cent deficit in 1986. This has, perhaps, led to a nearly same values of β almost throughout the year.

1.2.5. Fig. 4 shows the ratio of the values for Ahmedabad with reference to Bhavnagar. The figure clearly indicates that the variation, if any are marginal due to increased atmospheric pollution mainly on account of urbanisation. H_d and β respond in a similar way and are better indication on the sky condition.

1.2.6. The seasonal values (Table 1) do not show any appreciable changes at the two stations. The global radiant exposure H_g and the turbidity β show that in 1985-86. They are lower in Ahmedabad by 10 per cent and Bhavnagar had a 15 per cent lower H_d during this block as compared to 1970-71 block. This is inspite of Ahmedabad having had fairly good pre-monsoon showers. It was not so in the case of Bhavnagar. The 20 per cent higher value of H_g at Ahmedabad had reduced to a just 4 per cent and that the turbidity β had increased quite large over Ahmedabad by over 14 per cent. The monsoon rainfall was less by nearly the same order 40-45 per cent (Table 2) at both the places and both had excess rainfall during the post-monsoon period.

1.3. *Comparison between Pune and Nagpur*

Pune (18.53°N) is on the eastern side (rain shadow area) of the Western Ghats and has over the years seen an explosion of industrial and consequent urban development activities. Nagpur (21.10°N) is in the

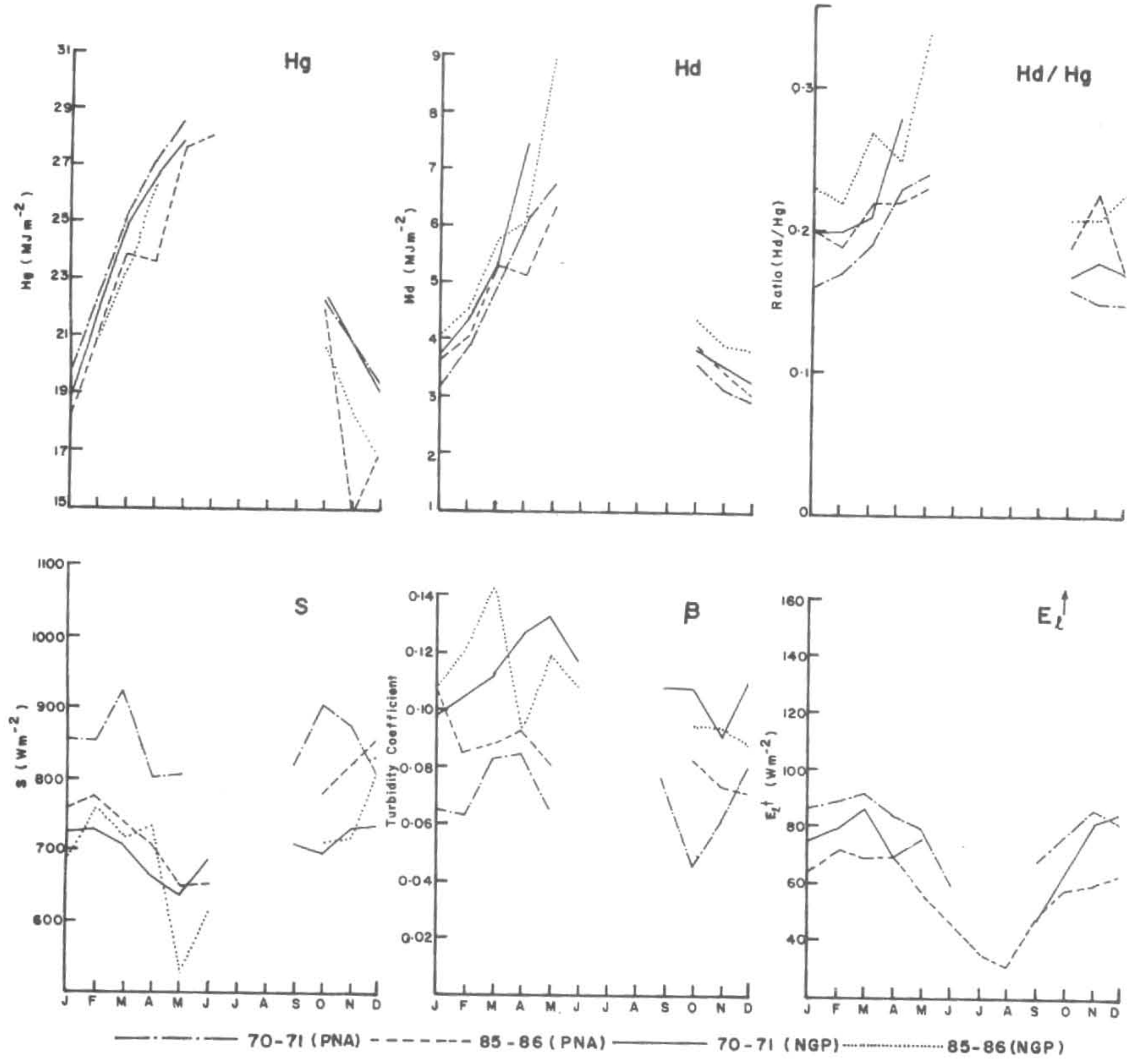

Fig. 5. Radiometric quantities at Pune and Nagpur

central parts and just south of the Satpura ranges. There has been some industrial development activities.

1.3.1. Fig. 5 gives a surprising feature that Pune and Nagpur receive nearly same H_g. Pune receiving a slightly higher irradiance. In 1985-86, the percentage difference has further shrunk between the two cities, Pune apparently becoming less transparent.

1.3.2. H_d values, however, show that on an average Nagpur had only 4 per cent higher irradiance than Pune during 1970-71 and this has surprisingly increased to 19 per cent in 1985-86. The highest difference is seen during November to February season. One possible cause may be that Pune is subjected to the westerly sea breeze which may carry the dust particles off to the east of Pune. Such cleansing mechanism will not be available in Nagpur. Further, Nagpur has registered a phenomenal increase in urbanisation around the observational site.

1.3.3. Fig. 5 shows the relative values of S at the two places over the two blocks. Here again Nagpur receives

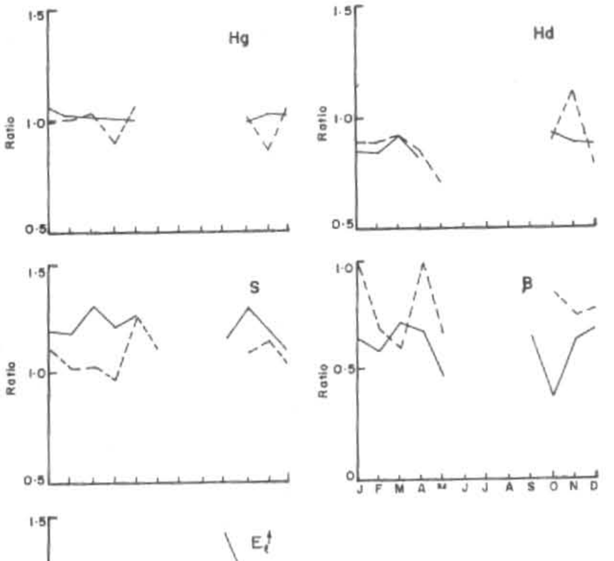

Fig. 6. Ratio of radiometric parameters at Pune and Nagpur

much lower irradiance both during 1970-71 block (17 per cent) and 1985-86 block (12 per cent). Even the fairly well spread rainfall activity over Nagpur (Table 1 of part I) does not cause any increase in S. In addition to the cleansing westerlies, the higher incidence of S may, perhaps, also due to the differences in the elevation above the mean sea level. Pune is 555 m and Nagpur 308 m. A reference to Figs. 6 & 7 of part I shows that the annual average value of S at Pune has decreased by 11 per cent from 850 Wm^{-2} in 1970-71 to 753 Wm^{-2} in 1985-86. Nagpur also shows a decrease of 16 per cent from 703 Wm^{-2} in 1970-71 to 660 Wm^{-2} in 1985-86. However, the percentage differences between Pune and Nagpur is much reduced during 1985-86 as compared to 1970-71.

1.3.4. The turbidity coefficient gives a better picture of the turbid sky over Nagpur, The average value of β over Nagpur, however, remains nearly the same (0.111 in 1970-71, 0.106 in 1975-76, 0.100 in 1980-81 and again 0.113 in 1985-86 blocks). Over Pune, it is, however, 0.069 in 1970-71 and 0.085 in 1985-86, an increase of over 20 per cent. The β values also show a lower percentage difference in 1985-86 as compared to 1970-71. Pune has recorded an increase in almost all months over the 15-year period unlike Nagpur which has shown only a marginal increasing trend. Similar results are reported by Srivastava *et al.* (1992) as a result of analysis of the sunphotometer data. They found that the Nagpur has about 22 per cent higher value of turbidity (0.140) than Pune (0.109). They found a general increasing trend in the turbidity values at all stations. They conclude from the frequency distributions some of the stations show an increasing trend towards higher values. The higher factor is likely to be due to anthropogenic contribution.

1.3.5. It is in the outgoing terrestrial radiant energy field that the actual changes in the human environment are clearly seen. Nagpur is consistently having a lower $E_l^{*}\uparrow$. The annual difference is 7 per cent, Pune having 81 Wm^{-2} and Nagpur 75 Wm^{-2}. That the Pune sky gets cleaned quickly by rains and westerly winds is seen in the steady build up in $E_l^{*}\uparrow$ from September onwards during 1970-71. Nagpur also experiences similar trend but to a lesser degree. The 1985-86, however, shows an entirely different picture, Pune having $E_l^{*}\uparrow$ as low as 56 Wm^{-2} for its annual value as compared to a 55 per cent higher value of 87 Wm^{-2} at Nagpur. The decrease in $E_l^{*}\uparrow$ seen in Nagpur during April-June due to good pre-monsoon rains is also reflected here. Pune which on an average looses 81 Wm^{-2} during 1970-71 has only 56 Wm^{-2} in 1985-86, a drop of 31 per cent. Perhaps, this is something to be kept in view for future monitoring.

1.3.6. The ratio of the values between Pune and Nagpur with Nagpur as reference clearly bring out the effect of the developments at Pune. The marginally higher H_g at Pune has started showing signs of becoming lower than Nagpur. The values of H_d though nearly stable shows the increasing trend at Pune, S and β show appreciable changes very clearly. The ratio in S has reduced from an average of 1.2 to 1.1 while β ratios show sharp increases at Pune. The longwave radiant energy makes it evident that in 1985-86 more energy is being trapped in the atmosphere at Pune and returned to the earth.

1.3.7. The seasonal values also show drastic departures in 1985-86 when compared with those of 1970-71. (Table 1) The deteriorating environment condition in 1985-86 is rather evident. Pune of course had less rainfall during both the blocks (Table 2).

1.4. *Comparison between Ahmedabad and Calcutta*

Ahmedabad (23.07°N) and Calcutta (22.53°N) are located within the same latitudinal belt but one in a semi-arid region in the western parts of the subcontinent and the other, Calcutta in the Gangetic delta with good and well distributed rainfall. The annual rainfall

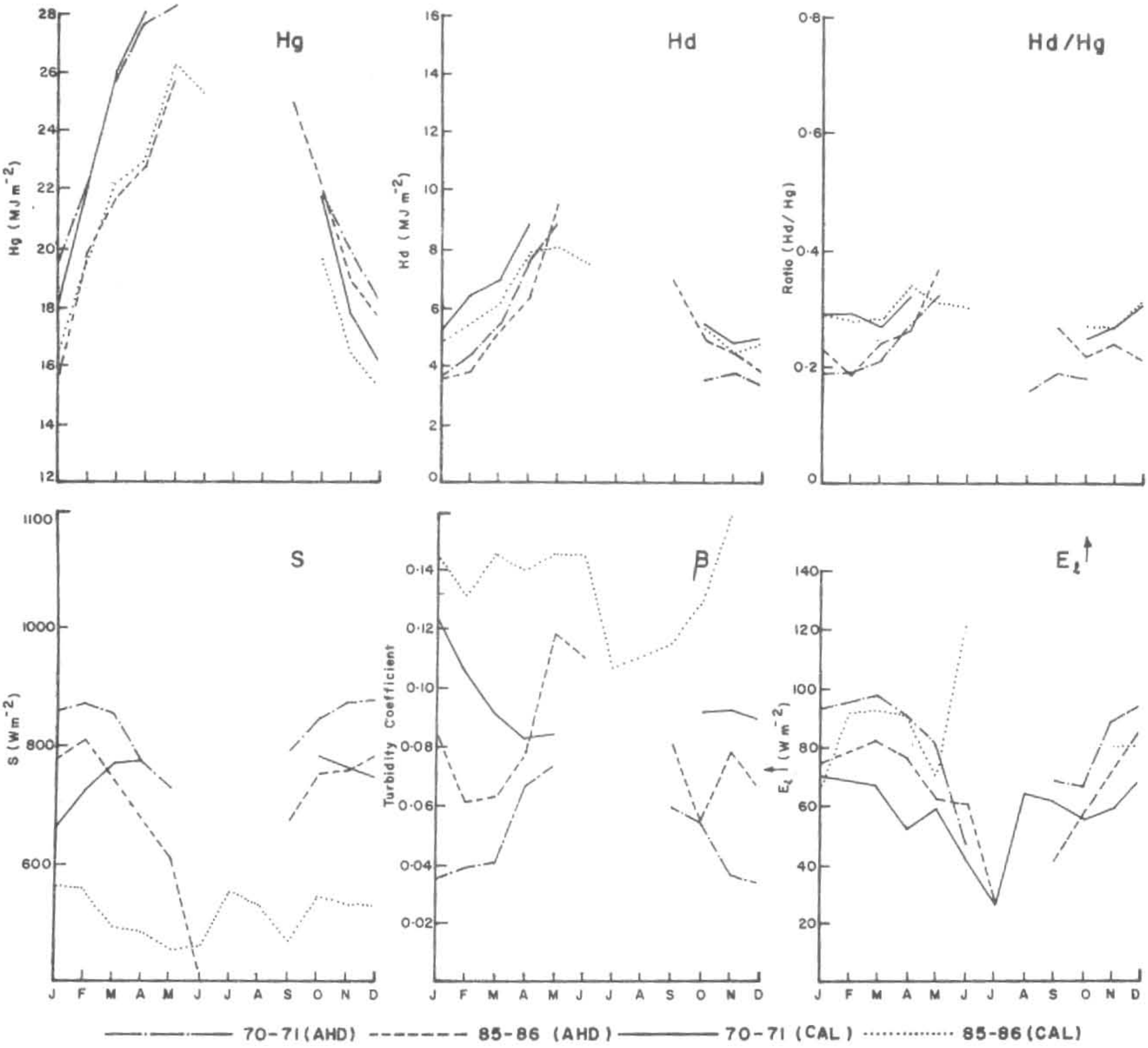

Fig. 7. Radiometric quantities at Ahmedabad and Calcutta

is of the order of 823 mm at Ahmedabad and 2211 mm at Calcutta. Located in the delta region and much nearer the coasts, Calcutta has more precipitable water in the atmosphere. Both places have had industrial activity over long periods, Calcutta having more heavy industrial installations. The population is also denser over Calcutta.

1.4.1. Considering the background conditions of the two places, global solar radiant exposures H_g for Calcutta should be very much less than that at Ahmedabad (Fig. 7). However, it is only 7 per cent lower on an average at Calcutta. An interesting feature is the large differences seen in the post-monsoon period, October-December, Ahmedabad receiving 10 per cent or more of H_g. As the season advances, the two places receive nearly the same radiant energy.

1.4.2. The diffuse component H_d gives the better idea about the relative conditions. H_d at Calcutta was as high as 36 per cent on an average as compared to that at Ahmedabad. The build up of dry dust over Ahmedabad is so high in the pre-monsoon period that H_d is just 17 per cent lower than that at Calcutta. The presence of dust particles and abundant water vapour keeps the atmosphere more turbid in Calcutta as compared to the efficient washing out by the monsoon rains of the dust particles over Ahmedabad. The rapid

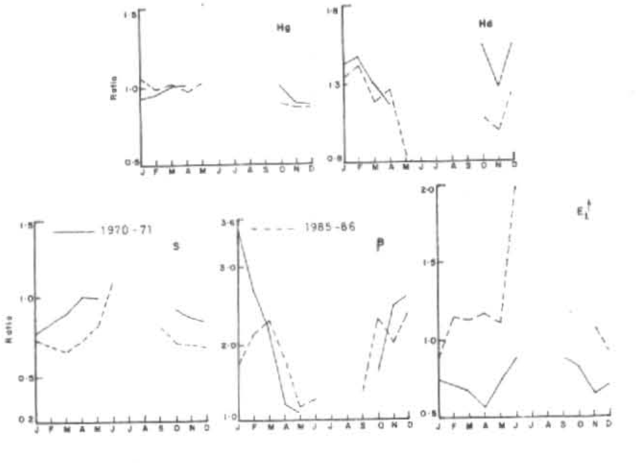

Fig. 8. Ratio of radiometric parameters at Calcutta and Ahmedabad

urbanisation at Ahmedabad later has caused H_d to increase, the average difference between Calcutta and Ahmedabad reducing to 13 per cent during 1985-86. The winter fogs, however, cause more diffused energy at Calcutta as compared to that at Ahmedabad.

1.4.3. Measuring the solar irradiance S at normal incidence is a direct index of the attenuation properties of the atmosphere. The attenuation of the Calcutta sky is higher and the irradiance is about 10 per cent lower than that at Ahmedabad (831 Wm^{-2}). The higher differences noticed in H_d during the post-monsoon season is reflected in values of S also. 1985-86 picture, however, shows that the differences between Calcutta and Ahmedabad are uniformly high, of the order of 29 per cent. The period November-March have the differences higher than 30 per cent, Calcutta receiving the lower irradiances. The 15 per cent difference in May at Calcutta may, perhaps, be due to the prevalent thundershowers at Calcutta and the absence of them at Ahmedabad. The larger attenuation is seen to be rather more at Calcutta—a drop of over 30 per cent from 746 Wm^{-2} during 1970-71 to 516 Wm^{-2} during 1985-86. The decrease at Ahmedabad during the corresponding period is about 13 per cent only.

1.4.4. Angstrom turbidity coefficient β at Calcutta is almost double that at Ahmedabad (Fig. 7) during 1970-71. The higher values of β during the post-monsoon period condition continues to be the same but the differences have reduced to some extent presumably due to the increased pollutants, dry in nature, at Ahmedabad. At Ahmedabad β has increased by more than 70 per cent while it is only 55 per cent in the case of Calcutta. This approximately agrees with that of diffuse component but is in variance with that of S. A possible explanation for the large attenuation in S at Calcutta without corresponding increase in β or H_d is that the hygroscopic particles grow in size and later absorb the irradiation as water droplets in the infrared range rather than act as scattering particles. This may have to be verified by measurements in more spectral bands.

1.4.5. The phenomenal increase in the atmospheric pollutants over Ahmedabad has been attributed in the previous paragraphs to be the cause for the "higher than 70 per cent" increase in β and the nearly 20 per cent increase in H_d over the 15-year period from 1970-71 to 1985-86. This is reflected in the terrestrial radiant energy ($E_l^*\uparrow$) field as well. $E_l^*\uparrow$ on an average had decreased by 14 per cent over the period. The 1970-71 block shows a 30 per cent lower loss in $E_l^*\uparrow$ over Calcutta (58 Wm^{-2}) than that at Ahmedabad (83 Wm^{-2}). The post-monsoon differences are again high.

The 1985-86 block, however, gives a different picture. Calcutta consistently (except in January) records a much higher loss (87 Wm^{-2}) as compared to that at Ahmedabad (71 Wm^{-2}). This would require a further study in depth.

1.4.6. The ratios of H_g values at the two places show that they are of same order during both the periods (Fig. 8). H_d values, however, are affected. This is amply supported by the lower ratios of β in 1985-86. S values, however, show much sharper decrease at Calcutta during the period. The poorer environmental condition at Ahmedabad is better reflected in the values of E_l^*. The average ratio of 0.70-0.75 of 1970-71 has increased to more than 1.00.

1.4.7. A study of changes in the seasonal values (Table 1) supports the trend in the deterioration of the environment at Ahmedabad. S had decreased by more than 30 per cent. H_d, however, shows varying degrees in the trend. Rainfall distribution (Table 2) has been uneven during 1985-86. The good pre-monsoon showers at Ahmedabad had reduced the difference which otherwise would have been more because of the lack of rainfall activity at Calcutta during the season. A good monsoon rains at Calcutta and a poor season at Ahmedabad has helped in reducing the differences in H_d.

2. Concluding remarks

The "developmental" activities leading to urbanisation enhance the injection of more particulate matter and the trace gases into the atmosphere. This is in addition to the dust load due to the natural phenomena like dust storms and dust raising winds and due to the loosening of soil matter degraded by the over use of the soil by increased population of an area. These pollutants are carried by wind to areas far away from the place of their origin. The radiometric studies offer good indications on these spreadings. Some of salient features thus seen are :

(*i*) The ratio H_d/H_g also shows an increasing trend. It has increased from 0.24 in 1959-61 to 0.32 in 1985-86 at Delhi. This ratio, however, remains nearly constant at places with higher industrial activity, around 0.22 at Ahmedabad and 0.30 at Calcutta. Bhavnagar also has a steady value, around 0.22.

(*ii*) The comparative studies bring out the impact of industrialisation fairly well over that of urbanisation particularly in the case of Delhi and Jodhpur.

(*iii*) The changes in the values over the 15-year period are not highly significant in the case of industrially developed areas like Ahmedabad and Calcutta. Dogniaux and Sneyers (1972) conclude that there is no significant changes in the radiation parameters over Uccle over a long period. Perhaps, this is due to the fact that the atmosphere over Uccle had already reached high levels of particulate matter concentration and further activities have only marginal effect in increasing the aerosol content.

(*iv*) Bombay data were not used for comparisons with those of Pune because the regular sea breeze over Bombay is likely to blow away the dust over to the mainland.

(*v*) The outgoing terrestrial radiant energy ($E_f^*\uparrow$) is the one which is closely indicative of the resultant of the atmosphere's interaction with the field. Almost all the stations indicate that the magnitude of outgoing terrestrial energy shows a steady decrease over the period. This means more and more of the energy is getting trapped in the atmosphere. The changes in Delhi and Jodhpur are marginal; in the case of Pune, a drastic reduction of over 25 per cent in E_f^* over 15-year period has been noticed. A more detailed study of $E_f^*\uparrow$ obtained in the network may be worthwhile and, perhaps, provide some indication of the trends.

(*vi*) Changes in both the polluting and scavenging mechanisms in the atmosphere are responsible for the observed variations in the global, diffuse and outgoing terrestrial radiant energy. There is every likelihood that these variations are the forerunners of possible climatic changes that are slowly creeping in. Since the time scales involved in such climatic changes are quite large, a close monitoring of the changes in all aspects of solar radiation is absolutely essential. This could enable us to take notice of undesirable trends in human activity and take corrective action well in time to avoid catastrophic damage to the atmosphere. On the other hand, it could also help us to detect trends which may be favourable for life on earth and utilize them to benefit all forms of life on earth. The results reported in this paper highlight the need for sustained efforts to gather continued, high quality radiation data from number of locations in the tropics.

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