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From the Journal, Asiatic Society of Bengal, Vol. LI, Part II, 1882.

Some further results of sun-thermometer observations with reference to atmospheric absorption and the supposed variation of the solar heat. —*By* HENRY F. BLANFORD, F. R. S., *Meteorological Reporter to the Government of India.*

[Received 28th December, 1882.]

In 1875, I read a paper before the Society, in which I discussed the temperatures observed with the sun-thermometer, at eleven Indian stations, during the years 1868-1874, and arrived at the conclusion that the solar heat had undergone a rapid increase from 1868 to 1871, and a less rapid decline afterwards, up to 1874.

The data were discussed according to various methods, but that on which I chiefly relied, as taking count of the largest amount of data, and being the best calculated to exclude the disturbing influence of atmospheric variation, was to select days on which there was either no cloud, or on which the cloud canopy, on the average of the 10 A. M. and 4 P. M. observations, did not exceed one-fifth of the sky expanse; and having taken the monthly averages of all the sun-thermometer readings on such days, to compare these averages for homonymous months at each station, in each pair of consecutive years. The months June, July, August and September were excluded from this comparison, inasmuch as, at nearly all the stations, the registers of which were discussed, these months are too cloudy to furnish a sufficient number of available readings. For the remaining months, the mean progressive variation of all the stations was taken, for each pair of years; and finally, the mean of the eight months gave the adopted variation for the consecutive years.

In order to ensure that such comparison should be valid, the investigation was restricted to stations, at which the same instrument had been in use in each pair of years compared, exposed in the same way, and on the same site. The curve of annual variation, resulting from these data, coincided, in a marked manner, with the sun-spot curve; but, in reality, striking as it was, this result was vitiated by errors from two sources, both of which tended to disturb and diminish the coincidence. One of these was the inclusion of the Silchar registers, which, as I afterwards discovered, had not been kept under similar conditions throughout; so that those of all the earlier years gave too low a temperature; and hence a marked *increase* of insolation temperature, shewn by this station in the later years, (when, according to the general result, that temperature was falling,) was not real. The other, the effect of which was however small, was an error of method:

the figures discussed were the actual readings of the sun-thermometers, readings which notoriously depend, not only on the intensity of the sun, but also on the temperature of the air; and it has been shewn by Köppen and others, that there is a cyclical variation of air temperature, of the opposite character to that disclosed in the curve, resulting from the registers of insolation temperatures. Hence it is at least probable that, the deduction of the air temperatures, and the discussion of the residual excess of temperature due to the solar action would have resulted in a curve of the same type, and of still greater amplitude.

Since this paper was published, I have attempted to carry on the comparison of the insolation temperatures, from year to year, by a rough and ready method; but as I am now convinced, one of very precarious validity. In the first place, all sun-thermometers are compared before being issued, with a common standard, by actual exposure to the sun, side by side, for 30 or 40 days, and their registers are corrected for the differences thus determined. All readings are recorded as excess temperatures (above those of the maximum thermometer in the shade), and in order to avoid the tedious process of picking out days of comparative clearness, I have taken simply the highest difference recorded at each station in each month, and the average of all these monthly maxima, as representing the solar intensity for the year. This method is, however, open to many objections, which I need not here specify; and I have therefore now reverted to my former method, (with one essential improvement), as the only one which is calculated to yield any trustworthy information, on the question of the supposed variation of the solar heat.

In the present paper, which is to be regarded only as a first instalment, I have taken the registers of eight stations, representing a great variety of climates, and which fulfil the three essential conditions, that the register of each station is that of the same instrument throughout; that it is exposed in the same manner, and also at the same place. Those of one and the same station are therefore as rigorously comparable in consecutive years, as can be ensured by the ordinary arrangements of our observations. The selected readings are those of days, on which the average estimated cloud at 10 A. M. and 4 P. M. did not exceed one-fifth of the sky expanse; and the figures compared, are those of the excess temperature, shewn by deducting the self-registered maximum shade temperature, for each day, from the reading of the maximum black-bulb thermometer *in vacuo*,* on the same day. It is unnecessary to give these first results *in extenso*. As an example of the data thus obtained for one year at a single station, I reproduce the following, which is a fair specimen of the whole:

* Except in the case of Vizagapatam, where the thermometer is not enclosed in an exhausted tube.

TABLE I.—*Observed differences of shaded and exposed (blackened bulb in vacuo) maximum thermometers, and cloud proportion, at Allahabad during the year* 1878 *on clear days.*

Date.	JANUARY.			FEBRUARY.			MARCH.			APRIL.			MAY.		
	Cloud Proportion.		Excess temperature, Radiation.	Cloud Proportion.		Excess temperature, Radiation.	Cloud Proportion.		Excess temperature, Radiation.	Cloud Proportion.		Excess temperature, Radiation.	Cloud Proportion.		Excess temperature, Radiation.
	10 h.	16 h.		10 h.	16 h.		10 h.	16 h.		10 h.	16 h.		10 h.	16 h	
1	0	0	63·1	...	...	...	0	0	64·2	0	0	58·4	...	...	...
2	0	0	61·9	0	0	63·1	0	0	64·2	...	...	...	...	...	...
3	0	0	65·0	...	...	...	0	0	52·6	...	...	...	...	...	...
4	0	0	64·8	0	0	59·4	0	0	61·8	...	...	...	0	0	57·5
5	...		...	0	1	61·5	0	0	61·4	0	0	63·6	...	...	...
6	0	0	62·9		...	...	0	0	61·2	0	1	62·3	0	0	60·0
7	...	...	...	...	...	...	0	2	62·6	...	...	...	0	1	57·5
8	1	0	64·2	...	...	...	0	2	63·7	...	...	...	...	...	...
9	...	...	...	...	...	...	0	0	63·8	0	2	60·3	0	0	58·6
10	...	...		...	...	...	0	0	61·3	0	0	58·6	3	0	58·1
11	...	...	...	...	...	...	0	1	59·9	0	0	57·3	0	0	57·7
12	...	...	...	0	0	*70·4	0	1	60·0	...	...	...	0	0	58·5
13	...	...	...	0	0	61·6	1	0	59·4	...	...	...	...	...	...
14		...	...	1	0	60·3	0	4	60·5	...	...	...	...	...	...
15		...	...	0	0	59·6	2	2	59·5	...	...	...	2	0	60·7
16	0	4	60·0	0	1	61·5	...	...	...	0	0	62·9	0	0	58·8
17	...	...	...	0	0	60·8	...	...	...	0	0	61·7	0	0	58·9
18	...	...	...	0	2	58·5	...	...	...	0	0	60·3	0	0	59·4
19	4	0	60·7	...	...	...	...	...	...	...	...	...	0	0	58·0
20	...	...	...	...	...	...	...	...	...	...	...	...	0	1	57·9
21	0	0	60·2	...	...	...	...	...	...	...	...	...	...	...	...
22	...	...	...	...	...	...	0	0	61·6	0	4	60·5	...	...	...
23	...	...	...	4	0	58·8	1	1	61·8	...	...	...	0	1	60·6
24	...	...	...	0	0	59·7	...	...	...	...	...	...	0	2	58·3
25	...	...	...	...	...	...	2	1	62·3	...	...	...	...	...	...
26	...	...	...	...	...	...	...	...	...	0	0	60·6	0	0	56·8
27	...	...	...	...	...	...	...	...	...	0	1	60·8	0	1	56·9
28	...	...	...	0	0	65·0	...	...	...	...	...	...	0	1	56·8
29	0	0	59·4	...	...	...	0	0	58·3	0	1	57·5	0	0	57·4
30	0	0	62·5	...	...	...	0	0	58·4	0	4	61·2	3	0	60·6
31	4	0	64·2	...	...	...	0	2	58·4	...	...	...	0	0	57·6
Means.	...	...	62·4	...	...	60·8	...	...	61·3	...	...	60·4	...	...	58·4

* There seems no reason to question this reading. A little rain had fallen the previous evening.

Date.	June.			September.			October.			November.			December.		
	Cloud Proportion.		Excess temperature, Radiation.	Cloud Proportion.		Excess temperature, Radiation.	Cloud Proportion.		Excess temperature, Radiation.	Cloud Proportion.		Excess temperature, Radiation.	Cloud Proportion.		Excess temperature, Radiation.
	10 h.	16 h		10 h.	16 h.		10 h	16 h		10 h	16 h.		10 h.	16 h.	
1	0	0	57·4	...	...	...	...	...	...	0	1	64·0	0	0	59 0
2	0	0	54·5	...	...	...	...	...	...	0	0	60 3	0	0	60·1
3	0	0	54·3	...	...	...	...	...	...	0	0	61·3	2	0	59·5
4	0	0	53·6	...	...	...	2	0	58·4	...	...	...	0	2	59·4
5	0	0	53 9	...	...	...	0	0	?	...	...	...	2	0	?
6	0	0.	53·7	...	...	...	0	0	55·8						
7	0	1	53·3	...	...	...	0	0	56·1						
8	0	0	53·4	...	...	...	0	0	55·6	...	...	...	0	0	59·0
9	...	...	...	...	...	...	0	0	56·6	0	0	58·8	0	0	58·6
10	0	4	53 5	...	...	...	0	0	57·1	0	0	59·5	0	0	58·7
11	4	0	53·4	...		...	0	0	57·6	0	0	58·1	0	0	62 9
12	0	2	52·1	...	...	...	0	0	57·4	0	0	59 8	0	0	62·9
13	...	...	...	...	...	...	0	0	58·9	0	0	58·6	0	0	61·1
14	0	2	54·0	...	...	...	...	...	...	0	0	57·8	0	0	62·2
15	...	...	...	...	...	...	...	...	...	0	0	59 8	0	0	64·3
16	0	0	51 4	...	...	...	...	...	...	0	0	60·0	0	0	61·4
17	0	4	53·9	...	...	...	1	1	61·2	0	4	60·6	0	0	60.8
18	...	...		...	...	...	0	1	58 0	...	...	...	0	0	60 3
19	0	4	54·8	...	...	...	0	0	58 2	...	...	...	0	0	64·3
20	...	...	...	...	...	...	0	3	57·4	...	...	...	3	0	61·8
21	0	0	50·9	...	...	...	0	0	56·7	0	0	59·2	0	0	64 4
22	...	...	...	...	...	...	0	0	57 6	0	0	59·5	0	0	64·8
23	...	...	...	...	...		0	0	59·0	0	0	55·2	0	0	65·1
24	...	...	...	1	2	56·7	0	0	59·5	3	0	60·6	0	0	63·0
25	...		...	...	...	...	0	0	59·4	0	0	60·0	0	0	6[illegible]·9
26	...	...	...	...	...	...	0	0	60·1	0	0	61·3	0	0	63·1
27	...	...	...	...	...	...	0	0	60·5	0	0	60·0	0	0	63·5
28	...	...	...	...		...	0	0	61·3	1	0	59·7	0	0	64·0
29	...	...	...	2	2	66 6	...	...		0	1	66·4	0	0	62·8
30	...	...	...	...	...	...	1	2	59·7	0	1	66·2	0	0	60 6
31	...	...	...	...	...	...	0	1	59 2	...	...	...	0	0	59·4
Means	...	...	53·6	...	...	...	...	...	58 3	...	...	60 3	...	...	61·7

Peshawar, being situated in a very dry region, affords sufficient comparable observations for every month of the year ; Jessore and other stations, within the reach of the heavy monsoon rains, do not afford a sufficient number of valid observations from June to September, and these months are accordingly excluded. Allahabad and Sirsa hold an intermediate place.

The mean value for each month of each year, obtained from such data as the above, is given in the following Table (II) for each station separately.

TABLE II.—*Monthly mean values of the excess of sun over shade temperatures at eight stations.*

Station	Year	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
Vizagapatam.	1875	34·3	38·1	31·2	29·1	25·4	...	...	...	...	27·6	31·0	36·4
	76	34·6	37·3	31·0	26·8	29·7	...	...	...	...	31·3	35·7	32·6
	77	28·2	27·1	27·6	28·1	28·5	...	...	...	...	28·3	32·4	32·2
	78	32·6	23·9	21·7	22·6	21·0	...	...	...	...	27·9	32·8	31·3
	79	30·0	28·1	26·1	21·9	23·4	...	...	...	...	26·3	26·0	27·8
	80	25·0	25·8	22·3	20·8	21·8	...	...	...	...	26·7	28·3	27·0
	81	26·1	23·9	22·1	20·8	21·3	...	...	...	...	28·9	27·5	27·7
	Mean	30·1	29·2	26·0	24·3	24·4	...	...	...	...	28·1	30·5	30·7
Sironcha.	1876	?	?	?	59·6	59·5	...	...	...	...	66·5	68·9	65·2
	77	64·8	63·1	59·7	60·5	59·9	...	...	...	...		57·3	48·7
	78	50·7	50·3	53·6	56·8	56·1		...	...	...	60·2	59·7	61·4
	79	58·8	56·9	53·8	52·0	53·1	...	...	...	...	57·6	59·4	58·2
	80	56·5	57·1	53·7	53·7	55·2	...	...	...	...	60·2	59·9	55·8
	81	54·8	54·3	52·9	53·9	52·3	...	...	...	...	56·1	57·1	55·7
	Mean	57·1	56·3	54·7	56·1	56·0	...	...	...	...	60·1	60·4	57·5
Bombay.	1876	?	?	?	?	?	...	...	...	...	61·6	61·4	61·7
	77	62·8	63·9	62·5	62·0	60·0	...	...	...	...	60·4	59·9	63·3
	78	62·0	62·7	61·4	60·1	59·1	...	...	...	...	57·0	55·4	58·5
	79	58·3	60·1	58·2	56·4	54·8	...	...	...	...	57·9	56·7	56·6
	80	57·0	56·7	55·2	54·5	54·8	...	...	...	...	55·7	55·9	55·7
	81	55·8	56·8	56·6	56·2	54·7	...	...	...	...	56·7	55·9	55·8
	Mean	59·0	60·0	58·8	57·8	56·7	...	...	...	...	58·2	57·5	58·6
Jessore.	1875	?	?	?	?	?	...	...	...	...	56·7	56·5	54·6
	76	55·0	55·7	55·0	53·4	54·3	...	...	...	...	64·0	58·2	60·0
	77	54·9	57·8	57·0	54·3	53·1	...	...	...	...	59·9	55·7	57·2
	78	56·0	53·9	52·2	53·5	56·9	...	...	...	...	56·5	57·6	55·1
	Mean	55·3	55·8	54·7	53·7	54·8	...	...	...	...	59·3	57·0	56·7
Hazaribagh.	1875	?	?	?	?	?	...	...	...	...	57·5	55·2	54·4
	76	54·1	55·2	56·0	55·0	56·6	...	...	...	...	59·2	57·6	58·2
	77	58·8	57·6	56·4	60·4	56·7	...	...	...	...	57·7	55·7	54·9
	78	57·0	54·1	55·3	55·8	58·0	...	...	...	...	58·8	57·8	57·2
	79	56·5	57·9	57·0	?	?							
	Mean	56·6	56·2	56·2	57·1	57·1	...	...	...	...	58·3	56·6	56·2
Allahabad.	1876	62·6	62·2	60·0	56·5	52·6	53·1	...	...	...	59·0	59·6	61·1
	77	59·5	63·2	59·7	58·3	56·1	53·2	...	...	...	58·5	58·6	60·5
	78	62·4	60·8	61·3	60·4	58·4	53·6	...	...	...	58·3	60·3	61·7
	79	60·7	60·4	59·8	58·5	57·9	56·8	...	...	...	59·8	60·5	60·6
	80	59·5	60·3	56·4	55·8	58·1	57·3	...	...	...	57·0	58·1	57·7
	81	58·8	57·4	58·0	56·3	56·4	58·8						
	Mean	60·1	60·7	59·2	57·6	56·6	55·5	...	...	...	58·5	59·4	60·3

Station	Year	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
Sirsa.	1877	...	64·0	61·6	61·7	61·2	57·0	56·1	...	57·5	59·8	57·9	59·3
	78	61·4	63·5	62·7	64·2	61·0	56·9	57·8	...	59·2	59·3	60·0	60·7
	79	61·3	62·2	63·6	62·6	61·5	56·8	59·9	...	60·5	58·7	62·2	60·0
	80	60·1	60·2	61·9	61·9	60·4	57·9	59·8	...	62·4	59·9	58·7	59·1
	81	61·0	61·9	66·6	63·2	60·5	59·4	63·3	...	62·1	58·8	60·7	59·0
	Mean	60·9	62·4	63·3	62·7	60·9	57·6	59·4	...	60·3	59·3	59·9	59·6
Peshawar.	1877	...	63·6	65·3	64·0	61·6	58·6	57·4	57·2	57·7	58·7	58·8	58·0
	78	59·9	61·9	61·1	61·6	58·9	52·5	48·8	48·7	54·6	55·7	54·9	55·1
	79	56·1	59·2	62·7	55·5	48·9	47·3	46·9	50·6	53·5	53·2	53·5	53·5
	80	57·5	64·9	59·6	60·2	55·7	51·3	50·5	54·8	57·8	58·4	55·2	57·2
	81	58·4	61·4	64·5	62·6	55·9	48·0	50·2	56·9	56·7	55·1	53·1	50·8
	Mean	58·0	62·2	62·6	60·8	56·2	51·6	50·4	53·6	54·9	56·2	55·1	54·9

It is evident, on a simple inspection of the above table, that the intensity of the insolation, on days apparently equally clear, undergoes a distinct annual variation. And moreover, that this variation is not determined by the thickness of the atmosphere traversed by the sun's rays, as the sun varies in declination; since it is different in character at different stations; and at some stations, *viz.* Allahabad, Vizagapatam and Bombay, is greatest in the winter, when the sun is at or near its lowest altitude, and the absorbing atmospheric layer, therefore, at its thickest. Its character, at the several stations enumerated in Table II, is best shewn in Table III, which exhibits the monthly anomaly of each station, computed on the general average of the months under consideration; *i e.*, not an annual mean, but the mean of as many monthly mean values as are shewn in Table II.

TABLE III.—*Annual variation of insolation excess temperature on clear (or but slightly clouded) days.*

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.
Vizagapatam	+2·2	+1·3	—1·9	—3·6	—3·5	...	...	...	...	+0·2	+2·6	+2·8	27·9
Sironcha ..	—0·2	—1·0	—2·6	—1·2	—1·3	...	...	...	...	+2·8	+3·1	+0·2	57·3
Bombay ..	+0·7	+1·7	+0·5	—0·5	—1·6	...	...	...	...	—0·1	—0·8	+0·3	48·3
Jessore ..	—0·6	—0·1	—1·2	—2·2	—1·1	...	...	...	..	+3·4	+1·1	+0·8	55·9
Hazaribagh .	—0·2	—0·6	—0·6	+0·3	+0·3	...	...	...	...	+1·5	—0·2	—0·6	56·8
Allahabad ..	+1·4	+2·0	+0·5	—1·1	—2·1	—3·2	...	...	...	—0·2	+0·7	+1·6	58·7
Sirsa ..	+0·3	+1·8	+2·7	+2·1	+0·3	—3·0	—1·2	...	—0·3	—1·3	—0·7	—1·0	60·6
Peshawar ..	+1·6	+5·8	+6·2	+4·4	—0·2	—4·8	—6·0	—2·8	—1·5	—0·2	—1·3	—1·5	56·4

This table shews that, under a sky apparently clear, the atmosphere is most and least diathermanous, respectively, in the following months at the stations enumerated; it being borne in mind that, except at the Punjab stations, and, in part, at Allahabad, the months of the summer monsoon are left out of consideration.

Stations.	Insolation. Greatest.	Insolation. Least.
Vizagapatam.	November, December	April, May.
Sironcha.	October, November.	March.
Bombay.	February.	May.
Jessore.	October.	April.
Hazaribagh.	October.	Decr., Feby., March.
Allahabad.	February.	June.
Sirsa.	March, April.	June.
Peshawar.	February, March.	July.

The results of the laboratory investigations of Professor Tyndall, as well as Mr. S. A. Hill's discussion of Mr. Hennessey's actinometric observations at Mussooree, obviously suggest the vapour constituent of the atmosphere as the variable element on which the actinic absorption of the atmosphere, may be expected to depend. And, on comparing the above results with the monthly averages of vapour tension, humidity and cloud proportion, (the last being regarded as an index of the relative humidity of the higher atmospheric strata), this expectation is confirmed in the case of the two coast stations Bombay and Vizagapatam; at least, with a near approximation. The results of the comparison in the case of these two stations are as follow: (Table IV, A). The maximum phase of each element is indicated by an (*) the minimum by a (†).

Table IV.—*Comparison of the annual variation of insolation temperature on clear days with those of vapour tension, relative humidity and cloud proportion.*

A.—*Coast stations.*

		Jan.	Feb.	Mar	April.	May.	Oct.	Nov.	Dec.
Vizagapatam.	Insolation..........	30·1	29·2	26·0	24·3†	24·4	28·1	30·5	30·7*
	Vapour Tension	·586	·644	·754	·853	·916*	·818	·663	·553†
	Relative Humidity ..	65	64†	66	68	69	72*	66	64†
	Cloud	1·74	1·44†	1·76	2·66	4·18	4·50*	3·23	2·31
Bombay.	Insolation..........	59·0	60·0*	58·8	57·8	56·7†	58·2	57·5	58·6
	Vapour Tension	·583†	·616	·720	.822	·886*	·850	·700	·627
	Relative Humidity ..	70†	70†	73	75	75	81*	71	70†
	Cloud	1·60	1·38†	1·91	2·38	4·12	4·42*	2·22	1·76

The chief point in which the inverse variation of insolation and humidity, otherwise distinctly indicated, seems to fail is, that the minimum of the former, at both stations, occurs in April or May, while the maximum of the latter as tested by *relative* humidity and cloud proportion falls in October; but, as regards the *absolute* humidity of the lower atmosphere, the coincidence holds good. And it will presently be seen that there is good reason why, other things being equal, the atmosphere should be somewhat more diathermanous after than before the beginning of the rains.

When, however, we turn from the coast stations to those in the interior of the country, where moreover, the range of insolation temperature is in some cases greater, this concomitance of absolute humidity and atmospheric absorption, which holds good at maritime stations, fails more or less completely; and it is evident that the latter is mainly determined by some condition of a very different nature.

TABLE IV.—B. *Interior.*

		Jan.	Feb.	Mar.	Apr	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.
Jessore.	Insol.	55·3	55·8	54·7	53·7†	54·8	...	...	...	...	59·3*	57·0	56·7
	Vap.Ten	·416†	·470	·631	·797	·890*	...	...	...	...	·857	598	·495
	Rel.Hum	60	55†	55†	62	72	...	...	...	...	78*	68	63
	Cloud	1·50	1·76	2·74	3·36	4·73*	...	...	...	..	4·66	2·10	1·32
Hazarib.	Insol.	56·6	56·2†	56·2†	57·1	57·1	..	...	...	...	58·3*	56·6	56·2†
	Vap.Ten.	·257†	·267	·288	·325	·523	...	...	...	...	552*	346	·266
	Rel.Hum.	51	44	36	32†	44	...	...	...	...	66*	53	52
	Cloud	2·36	2·11	2·58	2·62	3·25	...	...	...	...	4·11*	2·03	1·92†
Sironcha.	Insol.	57·1	56·3	54·7†	56·1	56·0	...	...	...	...	60·1	60·4*	57·5
	Vap.Ten.	·445†	·484	·510	·570	·627	...	...	...	...	·727*	·564	·462
	Rel Hum.	60	54	45	41†	43	...	...	...	...	72*	67	64
	Cloud	1·26†	1·54	1·60	1·75	2·61	...	...	...	...	3·46*	2·64	1·55
Allaha.	Insol.	60·1	60·7*	49·2	57·6	56·6	55·5†	...	...	...	58·5	59·4	60·3
	Vap.Ten.	336†	·359	·404	·449	586	·765*	...	...	...	·645	414	·345
	Rel.Hum.	67	60	46	36†	42	52	...	...	...	68*	63	68*
	Cloud	1·93	2·22	1·89	1·43†	1·61	4·39*	...	...	...	1·48	0·93	1·63
Sirsa.	Insol.	60·9	62·4	63·3*	62·7	60·9	57·6†	59·4	...	60·3	59·3	59·9	59·6
	Vap.Ten.	·221†	·254	·312	357	·455	·597	787*	...	·660	·375	·249	·233
	Rel.Hum.	52	50	42	36	35†	40	58	...	53	38	39	62*
	Cloud	2·76	4·33*	4·17	3·70	2·93	3·24	5·20	..	2·87	1·03†	1·46	2·53
Pesh'war.	Insol.	58·0	62·2	62·6*	60·8	56·2	51·6	50·4†	53·6	54·9	56·2	55·1	54·9
	Vap.Ten.	·209†	·227	·333	·407	·450	·527	667	·746*	·573	·367	·258	·230
	Rel.Hum.	59	57	57	54	43	40†	49	59	53	47	55	62*
	Cloud	3·73	4·33	4·50*	4·12	2·84	2·15	2·16	2·98	1·57	1·44†	2·08	3·43

A feature common to all these stations, and, at first sight, sufficiently remarkable, is that, at all, the month in which the maximum insolation, (or the least atmospheric absorption) occurs, is one characterized by a high proportion of cloud, indicating comparatively high humidity in certain of the higher atmospheric strata. In the case of Hazaribagh and Peshawar, the most cloudy months of the whole year, (or as far as is shewn in the tables,) are also those in which the insolation is greatest; at Sironcha and Sirsa, the greatest insolation occurs in the month immediately following that of most cloud; and, both at Sirsa and Jessore, the average cloud proportion, at the epoch of the former, differs by only an insignificant amount from the maximum. At Allahabad, the maximum insolation temperature coincides with a secondary cloud maximum, (that of the winter rains). It appears, therefore, that the rule, at stations in the interior of the country, is, in a measure, the reverse of that which we have found to hold good for the coast region; and that a humid state of the cloud-forming strata of the atmosphere, as indicated by the cloud proportion, is coincident with more than average diathermancy.

The association of a high degree of insolation with a highly humid state of the atmosphere has been prominently noticed both by the late Baron Hermann von Schlagintweit* and Mr. J. Park Harrison,† and each has suggested an explanation. That put forward by Mr. Park Harrison is based upon experimental results, which, as far as they go, appear to be perfectly valid. He finds that, when clouds are clustered about the sun, without obscuring it, the (probably reflected) heat, from the illuminated clouds, raises the equilibrium temperature of the sun thermometer, sometimes by several degrees; and moreover, that "the action does not appear to be confined to days on which there is *visible* cloud, for even on cloudless days, (so called) very high readings of solar radiation appear to be due to the presence of opalescent vapour," and that "an apparent increase of solar radiation occurs, as the sun enters a white cloud, of sufficient tenuity to allow free passage to its rays." Now with respect to the effect of visible clouds about the sun, it is very probable that many cases, which may be observed in the original registers, in which the maximum insolation temperature exceeds by several degrees that attained on other days in the same month, may be due to this cause. But observation with the actinometer shows that diffused amorphous cloud, which simply lowers the tint of the sky, making it pale and sometimes almost colourless, far from increasing the insolation, greatly reduces it.‡ And it is the frequent presence of

* Proc. Roy. Soc. vol. XIV, p. 111.

† Proc. Roy. Soc. vol. XV, p. 356; also vol. XVII, p. 515 and Phil. Mag. 4th Ser. vol. 39, pp. 70 and 299.

‡ Abundant evidence of this is afforded by the actinometric observations made at Alipore and printed by the Solar Physics Committee of the Royal Society in Appendix of their report.

this amorphous cloud, in the driest weather, to which I would attribute, in part, the low average temperatures of the (as recorded) cloudless months; but there is another absorptive agent, which has not been noticed by either of the authorities above quoted, and which is certainly much more powerful in dry than in damp weather, and to observers on the plains of India, is not easily separable from what I have above termed amorphous cloud; since, when seen from below, it has, like the latter, the effect of lowering the tint of the sky. This is the impalpable haze, which, as a general rule, and always in the dry season, rests on the plains of India, extending frequently to heights much exceeding 7,000 feet, and sometimes extends over the outer Himalaya, in such density, that, at Simla in the months of May and June, at a height of more than 7,000 feet, the hills, four or five miles distant only, are sometimes almost or quite invisible. The independence of these two absorbing agents is only observable at considerable elevations, and in certain states of the atmosphere; and the following observation, communicated to me by Mr. J. B. N. Henessey, M. A., F. R. S., whose experience in actinometric work invests his observations with unusual importance, is therefore especially interesting. "You remark" he writes on "the paleness" of the sky at Calcutta. Now, last April and May, having coached three of my assistants to use the actinometer exactly as I do, I left them to do the bulk of the observing. The sky, at first, was quite blue; and standing on the Mussoorie ridge, the Dehra valley with the Sivaliks beyond, and the plains, still further away, were all well seen. As the dry weather progressed, fires, as usual, appeared in the Doon, giving rise to smoke; and this, aided by dust, gradually filled the valley and dimmed objects in that direction by means of what may be called a *smoke* haze. The actinometer however stood at 6,940 feet above the sea, while Dehra station is only 2,200 feet. The haze lay a long way below us; at a guess, say 3,000 feet, and, to all appearances, hanging over the Doon only. At the time however a brisk south wind blows here daily, increasing in strength as the day advances, so that, at first, I paid little attention to my assistant's remarks as to the rising of the smoke, until, at last, the observations began to shew inconsistencies, which, however, were complicated by the fact, proved in previous years, that actinometric maximum radiation occurs *before* apparent noon. On watching the phenomena, I saw this. Far above me, at a guess, not under a mile, very thin and very light yet defined clouds were being driven northwards as the wind blew. I say *clouds*, from want of any other name; they were *white*, not brown or yellow, as if of steam, with soft graceful outlines along the advancing edges, which could be seen by watching against the blue sky. Imagine something between a mist and a cumulus, very thin and quite white. Now this steam-cloud (a mere phrase) was, say, a mile above, and the smoke ½ a mile below, and there was nothing to show that the former was fed by the latter. No doubt my steam-cloud would induce *paleness* of sky, an evil which you speak of as prevailing at Calcutta; and it is highly probable that such steam-clouds, not by any means prominent, were driven over Mussoorie for days and days in the dry weather at least. What were they composed of? not smoke and not dust as far as I could judge.

"As to the haze, to all appearances, *dust* haze, being visible *between showers*, as you mention, we have noticed that here too. I have water barrels at the corners of our house; they are fed exclusively by iron pipes from a clean iron roof. *After* a few showers had fallen, I had the barrels well cleaned in my presence; the water was clear. Subsequently a heavy fall of rain occurred, I examined the barrels, expecting the water to be quite clear; instead, the water was charged with yellow clay; and yet, after the first showers, I should have thought that the air was too saturated with moisture, not to arrest dust a long way below 7,000 feet.

"Again last year, in the dry weather, I was watching day after day for actinometric weather; the hills were obscured or dimmed by haze, obviously dust haze. I can see the *Chor* where I write; between that mountain and this, the dust haze was quite plain; suddenly there was a change in the haze about 2 P. M. one day, it *was* a *sheet;* it began to roll about in waves and I may say visibly changed into clouds of vapour, which rose like ordinary clouds, leaving me a clear view of the *Chor*, &c., looking *quite blue.* Note there *was no rain.*"

It results from what has been said above, that (excepting on the coast) up to a certain point, which cannot be strictly defined, a humid condition of the atmosphere tends to increase the readings of the sun-thermometer and the actinometer; indirectly by reducing the (dust?) haze which in dry weather forms a absorbing stratum of many thousands of feet in thickness, and directly by causing the formation of cloud masses which when clustering round the sun, reflect the solar rays and add the effect of the reflected to the direct radiation. On the other hand the amorphous cloud which exists at great elevations in dry weather and especially in the winter and spring months, and is generally only appreciable by its lowering and blanching the sky tint, is also a potent absorber. The sheets of *Pallio-cirrus* and *pallio-cumulus* which are result of a highly humid condition, and are especially the clouds of the rainy season, are of course the most impervious of all solar screens.

Since then, the athermancy of the atmosphere is enhanced by such opposite conditions of dryness and humidity, and, at present, we have no such records of these conditions as might enable us to frame a law of numerical concomitance, and thus apply an empirical correction to our actinometric results, it might seem almost hopeless to seek for evidence of any variation of the intensity of the solar radiation, in the registers of insolation temperatures, or even those of actinometric observations on the plains of India; but this I think would be a hasty conclusion. The effect of cloud reflection may be pretty well eliminated by careful selection, and even although the effect of the solar variation (supposing such to exist) may be small in comparison with those effects which depend immediately on atmospheric absorption, since in comparing the registers of different years, the former must affect all stations simultaneously and similarly, whereas the latter vary indefinitely at different stations, it may yet be possible by taking the mean result of a large number of stations in different parts of the country, to eliminate such atmospheric effects, as continue to manifest themselves prominently in the individual registers, after taking such obvious precautions as have been specified above; and I am the more encouraged to entertain this view, by the very striking coincidence between insolation and sun-spot frequency which resulted from my former investigation. And the results of the present attempt, though less striking than the former investigation had led me to anticipate, are, still, not such as to discourage further enquiry in this field. They must however be regarded, at present, as provisional only; and, indeed, the number of stations here considered is too small to admit of any other estimate of their validity.

TABLE V.—*Progressive differences of insolation temperatures on clear days from the monthly means of Table II.*

	1875-6.		1876-7.		1877-8.		1878-9.		1879-80.		1880-81.	
	Stations.	Differences.	Stations.	Differences.	Stations.	Differences.	Stations.	Differences.	Stations.	Differences.	Stations.	Differences.
January	1	+ 0·3	4	— 4·9	6	— 8·3	7	— 4·3	6	— 9·6	6	— 0·7
February	1	— 0·8	4	— 4·7	8	—29·2	7	+ 6·6	6	— 1·9	6	— 9·3
March	1	— 0·2	4	— 1·3	8	—20·5	7	+ 4·1	6	—18·1	6	+11·6
April	1	— 2·3	5	+10·3	8	—14·3	6	—18·8	6	0	6	+ 6·1
May	1	+ 4·3	5	+ 1·6	8	— 7·7	6	—14·9	6	+ 5·6	6	— 9·4
June	0	...	1	+ 0·1	3	— 6·6	3	— 2·1	3	+ 5·6	3	— 0·3
July	0	...	0	...	2	— 6·9	2	+ 0·2	2	+ 3·5	2	+ 3·2
August	0	...	0	...	1	— 8·5	1	+ 1·9	1	+ 4·2	1	+ 2·1
September	0	...	0	...	2	— 1·4	2	+ 0·2	2	+ 6·2	2	— 1·4
October	3	+12·7	6	—13.4	8	—13·0	6	— 4·9	6	+ 4·4	5	— 5·3
November	3	+ 8·8	6	—21·8	8	+ 2·2	6	— 4·8	6	— 2·2	5	— 3·7
December	3	+ 5·4	6	—22·0	8	+ 7·9	6	—10·7	6	— 5·5	5	— 5·8
Sums	14	+28·2	41	—56·1	70	-106·3	59	—47·5	56	— 7·8	53	—12·9
Means	...	+ 2·0	...	— 1·4	...	— 1·5	...	— 0·8	...	— 0·1	...	— 0·2

The data, being those given in Table II, have been summarized in the above Table to shew the mean variation, from year to year, in the following manner. The differences of the corresponding months, in each pair of consecutive years, being first taken out and tabulated, the sums of these differences in the same pair of months and years is computed from as many stations as are represented. These monthly sums and the number of stations yielding them, in each case, are shewn in the table, and the annual sums and means of the whole given at foot.

If the first pair of years be rejected as furnishing insufficient data, the table would seem to shew a continuous fall of solar intensity; rapid from 1876 to 1879, and subsequently only just appreciable. As is well-known, the sun-spot minimum occurred in the 1st quarter of 1879, so that it cannot be said that the present table shews a decided concomitance of the solar intensity and sun-spot frequency such as resulted from the former discussion. At the same time, if not conclusively favourable, still less is it conclusively adverse to the former conclusion, and the enquiry appears to be well worth following up with such further evidence as the Indian registers may yield. This I propose to do.