affects the coast stations; and attributes this to the want of more complete knowledge of the contour of the surface, both above and below the sea-level, in these parts. But his own method, in the case $m=50$, remarkably reduces the effects of local attraction at stations on the arc of meridian and out at sea (in Minicoy, an island 250 miles west of Cape Comorin or Punnæ); for the sensible negative quantity at Damargida and positive quantity at Kalianpur indicate a deficiency of matter below the first and an excess below the second, which exactly tally with the results independently brought out by relative deflections of the plumb-line as obtained by the survey: and the two large and most important effects, negative at Kaliana and positive at Minicoy, may be said to be almost annihilated by this method of correction. This last case of an *excess* of gravity out at sea (where the surrounding ocean has a deficiency of matter) being explained by his method, he regards as a very strong argument in its favour. And he finishes by saying that if his method is thus far successful in the particular supposition of the distribution below, whether in excess or defect, being *uniform*, which is most likely not strictly the case, there is every reason for concluding that pendulum-observations give support to the hypothesis regarding the Constitution of the Earth's Crust, when viewed on a large scale, admitting of local peculiarities, like the deficiency of matter near Damargida and the excess near Kalianpur, and the similar deficiency near Moscow.

III. "Actinometrical Observations made at Dehra and Mussoorie in India, October and November 1869, in a Letter to the President." By Lieut. J. H. N. Hennessey. Communicated by the President. Received September 7, 1870.

Mussoorie, July 22, 1870.

My dear Sir,—In continuation of my last communication, dated April 25, 1870, I have now the pleasure to forward the actinometrical observations taken, during portions of October and November 1869, with the instruments of the Royal Society, and in compliance with the suggestions which the Committee of the Society made for my benefit.

(2) The two actinometers are of the kind invented by the Rev. G. C. Hodgkinson, and described by him in the Proceedings of the Royal Society, No. 89, vol. xv. Further description or allusion is therefore unnecessary, unless I add that the instrument is easily and accurately worked after but moderate practice, and that it is little liable to accident if rolled up in a padded sheet and packed within its own metal tube. It, however, imposes sensible drawbacks, from the delays incurred in throwing off a *suitable* amount of fluid into the chamber; and as this adjustment becomes deranged by any considerable alteration in the radiation, it is impossible to

continue a series of observations for any lengthened period (as, say, two hours) without introducing breaks of several minutes in its continuity.

(3) The two instruments used have been lettered by the observers A and B. The glasses, too, have been suitably marked as suggested by Sir John Herschel in the 'Admiralty Manual of Scientific Enquiry.' Actinometer B was used at Dehra by Mr. W. H. Cole, M.A., whose observations in sun and shade number 405 in all. The observations at Mussoorie were made by myself with actinometer A; they are 315 in number. And as respects the chronometers, barometers, and thermometers employed, I need hardly add that these instruments were of a superior order and well verified, or that they are in ordinary use at the head-quarters of Colonel Walker, R.E., Superintendent of the Great Trigonometrical Survey of India.

(4) And with every facility for reading the last-named instruments, I regret having omitted to arrange for a more frequent reading of the barometer, and that the wet- and dry-bulb thermometers were not recorded. It, however, so happened that during the days of observation in October and November last the sky was beautifully clear, with the trifling exceptions noted in the records of observations; and there is no reason to suppose that any sudden changes occurred in the hygrometric conditions of the atmosphere. In future, however, when the actinometers can again be worked, more numerous readings of the barometer and thermometers will be duly recorded.

(5) The stations of observation were Mussoorie and Dehra. The direct distance between them is about nine miles. The former stands on one of the southernmost ranges of the Himalayas; the latter is in the valley Dehra, or Dehra Dhoon. The hypsometrical elements for these stations, given in the result-abstract and elsewhere, are taken from the records of the Trigonometrical Survey of India. It appears from these values that Mussoorie station is above that at Dehra about 4700 feet.

(6) The procedure agreed on between Mr. Cole and myself was to observe daily a simultaneous series at $11^h\ 40^m$ A.M. (mean of all the observed times), another series at noon, and a third at $0^h\ 20^m$ P.M., the reckoning being in apparent time. The slight deviations from these times which appear in the result-abstract are due to little accidental causes almost inseparable from simultaneous work. After four days of these series, each observer was to determine the amount of heat stopped by the glass of his instrument employed. In these experiments I was too busy otherwise to reciprocate Mr. Cole's observations of November 1. On the 3rd of November, however, we both observed the intended succession of groups (nearly); so that several of these are made to discharge a double duty, and are introduced in the after-discussion of relative radiation. On November 4 we each obtained a complete hourly series about the hours of 8 A.M. to 4 P.M. These results terminated for the time the reciprocal series of observations Mussoorie-Dehra. Subsequently, in April 1870, when we were

both at Dehra, we carefully compared the two actinometers A and B together. This was the only occasion during all our observations when light clouds occasionally passed over the sun. But as the two instruments were set up within 3 or 4 feet of one another, and as we both used the same chronometer and read our scales at the same instant of time, there appears no reason why the results should not be accurate, relatively speaking.

(7) The constants thus determined are as follows:—

Actinometer A { Factor No. 1, to convert readings with *glass on* into readings *glass off*. } = 1·09 { Obtained from six groups glass off and five groups glass on, comprising sixty-five observations in all.

„ B Factor No. 2, „ „ = 1·04 { Obtained from two sets of observations, each consisting of four groups glass off and three glass on, and comprising ninety-six observations in all.

Factor No. 3, obtained from comparisons between A and B comprising 112 simultaneous observations, of which the following is a result-abstract reduced to 32° Fahr. and expressed in tenths of A's scale (both glasses on):—

Apparent time.	A. Observed by J.H.N.H.	B. Observed by W. H. C.	B−A.	Apparent time.	A. Observed by W. H. C.	B. Observed by J.H.N.H.	B−A.
h m s				h m s			
11 26 0	819	832	13	11 44 0	788	806	18
0 8 0	828	830	2	0 25 0	804	817	13
0 51 0	758	781	23	1 51 30	794	816	22
2 11 0	786	794	8	2 31 0	666	681	15
Mean ...	798	809	12	Mean ...	763	780	17

Whence $\frac{\text{mean A}}{\text{mean B}} = \frac{780{\cdot}5}{794{\cdot}5} = 0{\cdot}982.$

We may also deduce

(W. H. C. at B) −(J. H. N. H. at A)=11.

(J. H. N. H. at B)−(W. H. C. at A)=17.

The accordance of these two average differences shows that no sensible "personal equation" appeared to exist between the observers.

(8) The observations simultaneous at Mussoorie and Dehra were, in the first instance, separated into groups, and combined group by group for a result. Subsequently groups were formed so as to include all the observations taken, subject to the following conditions:—

Seven (or fewer) sun-observations, with the intermediate observation in shade, were combined to produce one result.

Eight sun-observations, with the intermediate observations in shade, gave

groups of 5 and 4 sun-observations respectively (those in shade are here understood), the fifth sun being common to both groups.

Nine ditto, ditto, gave 5 and 5.

Ten ditto, ditto, gave 6 and 5.

Eleven ditto, ditto, gave 5, 4, and 4; and so on.

(9) The mean results by each group were next all corrected for excess of temperature above 32° Fahr., the Table of expansion for alcohol by Kopp, given in Gmelin's 'Chemistry,' being employed for this purpose. After this step the results by A were entered in the result-abstract Table and the corresponding values, in terms of A *glass off*, found by means of factor No. 1. The results by B were further corrected in the record of observations by means of factor No. 3. Being now in terms of A *glass on*, they were introduced into the result-abstract Table, and there reduced to A *glass off*, by means of factor No. 1.

(10) Thus the result-abstract Table contains the values obtained by each actinometer expressed in terms of A *glass on* as well as *glass off*. The latter values are those made use of in projecting the actinometric curves, and in the discussion of the observations. The former values will be useful should the Royal Society see fit to send me a third actinometer whose constant for reduction to the Kew standard has been duly ascertained. At present the required relation is wanting; for though Professor Stokes was so exceedingly kind as to visit Kew with the object of getting the actinometers A and B verified, the necessary observations could not be made from want of time.

(11) Turning, now, to the diagram of actinometric curves and to the result-abstract Table, it is readily seen that the solar radiation decreases from some time about apparent noon both towards sunrise and sunset. This hour-angle change is least perceptible for some ± 1 hour (or less) from noon—a condition which indicates that observations for relative or absolute intensity are most valuable when made during this interval. Indeed even desultory observations might acquire importance by being restricted to these hours, the absence of cloud, mist, haze, or other abnormal interposition being always supposed.

(12) But besides the hour-angle change, the intensity is liable to rises and falls brought about in only a few minutes of time. Any observer who has used the instrument could venture to affirm that these fluctuations are not due to fallibility of observation. Whether their magnitude varies with that of the intensity or otherwise may be a matter of interest to ascertain; and to this end series of observations, continued for as long a period as the construction of the instruments will permit, appear desirable.

(13) Again, there is a change of intensity from day to day, apparently not due to alteration in the sun's declination, so that the average *daily* curve (about noon) is higher or lower without any visible reason. It is interesting to notice that this daily change was common to Mussoorie and

Dehra. The two stations, it will be remembered, are about nine miles apart, and situated nearly on a common meridian.

(14) Collecting the results of observations, we obtain the following from simultaneous groups only :—

TABLE I.

		M*.	D*.	M−D.			M.	D.	M−D.
	h m s					h m s			
27th.	11 49 30	1007	876	131	3rd.	11 14 30	1001	930	71
	0 9 30	968	904	64		0 15 0			
	0 29 30	941	888	53		11 46 0	1013	912	101
						0 45 0			
	Mean	972	889	83		0 0 0	1006	908	98
						0 15 0	1015	929	86
28th.	11 40 0	955	887	68		0 30 0	1005	924	81
	0 0 0	969	883	86		0 45 0	1020	937	83
	0 21 30	928	884	44					
						Mean	1010	923	87
	Mean	951	885	66					
					4th.	8 3 30	847	718	129
29th.	0 3 30	984	895	89		9 11 0	943	821	122
	0 4 30					10 8 0	996	876	120
	0 21 30	965	907	58		11 10 0	1000	909	91
						0 11 0			
	Mean	975	901	74		0 6 30	986	913	73
						1 8 0	984	892	92
30th.	11 40 0	980	912	68		2 10 30	964	845	119
	0 1 30	977	903	74		0 9 30			
	0 18 30	983	919	64		3 9 30	911	758	153
						4 9 30	775	540	235
	Mean	980	911	69					
						Mean from $11^h\ 10^m$ to $1^h\ 8^m$.....	990	905	85

Collecting these average daily results for ± 1 hour (about) from noon, we have :—

TABLE II.

	M.	D.	M−D.
1869. Oct. 27.	972	889	83
28.	951	885	66
29.	975	901	74
30.	980	911	69
Nov. 3.	1010	923	87
4.	990	905	85
Mean	980	902	77

and $\frac{M}{D} = 1{\cdot}086$.

(15) In Tables I. and II. I have availed myself of none but actually simultaneous observations. We may, however, include every result at either station, provided the curve at the other station exists for the required time.

* M stands for Mussoorie, D for Dehra.

Thus at Dehra, October 28, we have the result 880 *observed*. The corresponding result at Mussoorie (*i. e.* at $11^h\ 15^m$) is found from the diagram to be 945. Proceeding in this manner, and taking averages of all results within 5 minutes of one another to make one result, we find :—

TABLE III.

		M.	D.	M−D.			M.	D.	M−D.
	h m s					h m s			
27th.	11 49 30	1007	876	131	3rd.	11 15 45	1002	927	75
	0 9 53	969	904	65		11 30 0	1008	918	90
	0 29 30	941	888	53		11 36 30	1010	916	94
						11 45 30	1013	912	101
	Mean	972	889	83		0 0 0	1006	908	98
						0 15 0	1015	929	86
28th.	11 15 0	945	880	65		0 30 0	1005	924	81
	11 20 0	943	881	62		0 45 0	1020	937	83
	11 41 30	956	890	66					
	0 1 18	967	876	91		Mean	1010	921	89
	0 21 30	928	884	44					
	0 33 30	937	885	52	4th.	8 3 30	847	718	129
						8 13 0	865	739	126
	Mean	946	883	63		9 11 23	943	823	120
						10 8 45	996	870	120
29th.	0 3 45	984	897	87		11 9 45	1001	905	96
	0 21 30	965	907	58		11 19 0	990	910	80
	0 32 0	964	895	69		0 8 0	987	913	74
	0 41 0	962	900	62		1 8 45	984	894	90
	1 20 0	958	891	67		2 10 0	964	845	119
	1 33 30	954	889	65		3 9 30	911	758	153
						4 8 0	780	546	234
	Mean	965	897	68					
						Mean from $11^h\ 9^m$ to $1^h\ 8^m$ ...	991	906	85
30th.	11 41 48	981	917	64					
	0 1 30	978	904	74					
	0 17 35	985	918	67					
	Mean	981	913	68					

And collecting the average daily results of Table III. for ± 1 hour from noon, we obtain :—

TABLE IV.

	M.	D.	M−D.
1869. Oct. 27.	972	889	83
28.	946	883	63
29.	965	897	68
30.	981	913	68
Nov. 3.	1010	921	89
4.	991	906	85
Mean	978	902	76

and $\frac{M}{D} = 1{\cdot}084$,

which values of M−D and $\frac{M}{D}$ are practically identical with those of Table II.

(16) As regards the complete day-curve observed on November 4, it

appears that while the radiation at both stations *increases* from 8 A.M. and 4 P.M. towards some time about noon, the difference M—D *diminishes*. In other words, the radiation at the lower station increases more rapidly than at the upper; and while at both stations the change is more rapid in the afternoon than in the forenoon, the relative change between forenoon and afternoon is greatest at the lower station.

(17) Mr. Hodgkinson, in his paper already referred to, quotes certain numbers obtained by Principal Forbes from his "free hand curve" of observations on the Faulhorn and Brienz, showing the relative intensity of the two stations. Calling his ratio $\frac{F}{B}$, the following may be contrasted:—

By Mr. Forbes.		From Table III., Nov. 4th, 1869.	
Hour.	$\frac{F}{B}$.	h m s	$\frac{M}{D}$.
		8 8 15	1·174
9	1·141	9 11 23	1·146
10	1·214	10 8 45	1·137
11	1·345	11 14 22	1·097
12	1·219	0 8 0	1·081
1	1·078	1 8 45	1·101
2	1·207	2 10 30	1·141
3	1·217	3 9 30	1·202
		4 8 0	1·429

where the heights of the stations are:—

	feet	
Faulhorn	8747	by Principal Forbes.
Brienz	1903	
Mussoorie	6937	from the records of the Great Trigonometrical Survey of India.
Dehra	2229	

In conclusion I gladly acknowledge that I am much indebted to my friend Mr. Cole, not only for his skill and industry in taking the observations at Dehra, but for his cordial cooperation in reducing and discussing them.

Hoping you continue in the enjoyment of good health, I am, dear Sir, with kind wishes,

Yours very truly,

J. H. N. Hennessey.

General Sir Edward Sabine, K.C.B., &c.,
Pres. Roy. Soc., London.

The record of actinometer observations has been posted in a separate packet *. The papers enclosed with this letter are the paper of actinometric curves and the result-abstract Table.

[* This record is preserved in the Archives for reference.—G. G. S.]

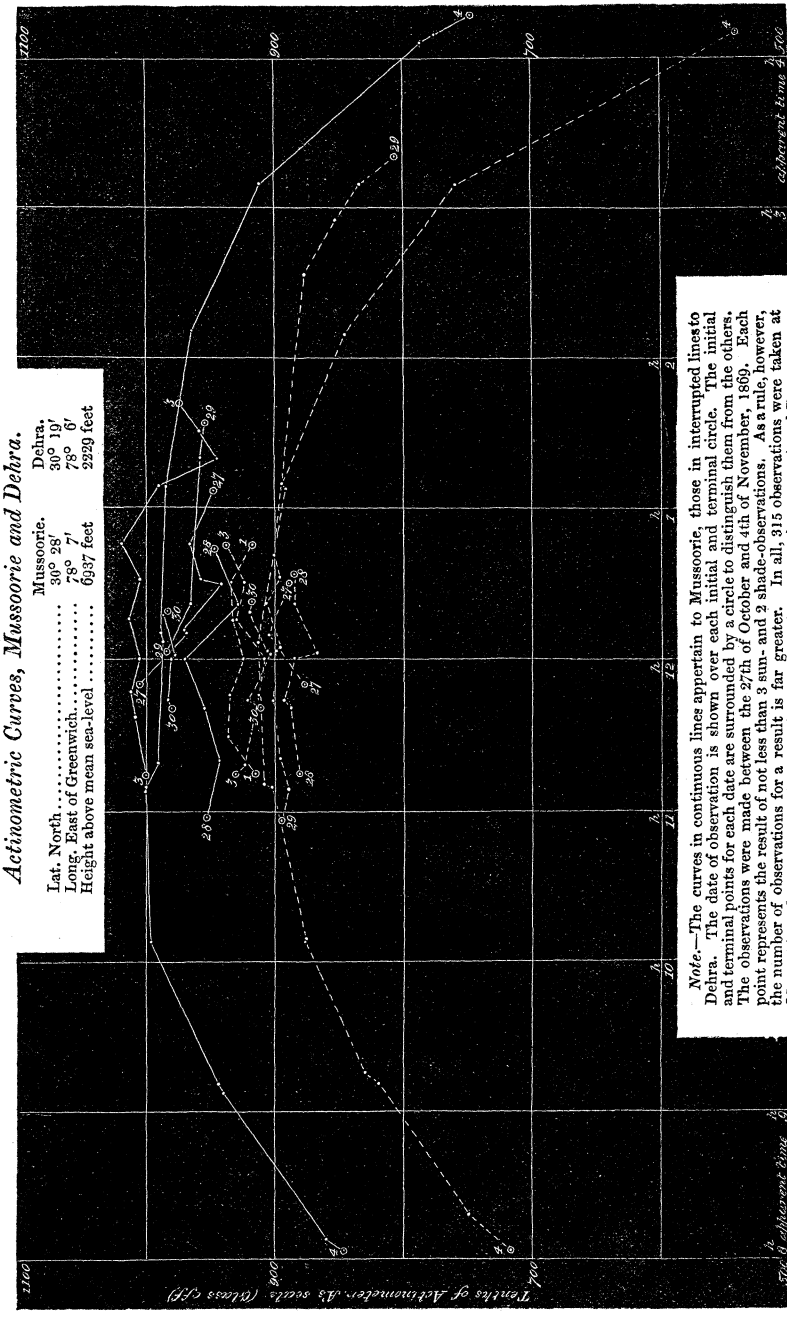
Result-abstract of Actinometrical Observations at Mussoorie on an outer range of the Himalayas, and at Dehra in the Dehra Dhoon, made by J. H. N. Hennessey, Esq., and W. H. Cole, Esq., M.A., of the Great Trigonometrical Survey of India.

Observations.			Mean results at Mussoorie observed with A and reduced to 32° Fahr.			Mean results at Dehra observed with B and reduced to 32° Fahr.		
In ⊙.	In ×.	Mean of the apparent times.	Nos.	In terms of A, glass *on*.	In terms of A, glass *off*.	Nos.	In terms of A, glass *on*.	In terms of A, glass *off*.
		October 27, 1869.						
		h m s						
3	2	11 49 30	1 5	924	1007	1 5	804	876
3	2	0 9 30	6 10	888	968	6 10	829	904
4	3	0 11 0	6 12	890	970			
3	2	0 29 30	13 17	863	941	11 15	815	888
4	3	0 31 0	13 19	878	957			
3	2	0 45 30	20 24	885	965			
4	3	1 7 0	25 31	869	947			
		October 28, 1869.						
4	3	10 57 0	32 38	874	953			
6	5	11 15 0	.....	.....	.....	16 26	807	880
4	3	11 20 0	39 45	865	943			
4	3	11 40 0	46 52	876	955	27 33	814	887
6	5	11 43 0	.....	.....	.....	27 37	818	892
4	3	0 0 0	53 59	889	969	38 44	810	883
5	5	0 2 15	.....	.....	.....	38 47	796	868
5	4	0 21 30	60 68	851	928	48 56	811	884
5	4	0 33 30	.....	.....	.....	56 64	812	885
5	4	0 43 30	69 77	868	946			
		October 29, 1869.						
6	5	10 56 0	.....	.....	.....	65 75	822	896
5	4	11 9 30	.....	.....	.....	75 83	816	889
5	4	11 21 30	.....	.....	.....	83 91	821	895
6	5	11 43 0	.....	.....	.....	92 102	827	901
6	5	0 3 0	.....	.....	.....	103 113	825	899
3	2	0 3 30	78 82	903	984			
3	2	0 4 30	.....	.....	.....	107 111	821	895
5	4	0 21 30	83 91	885	965	114 122	832	907
4	3	0 32 0	.....	.....	.....	122 128	821	895
4	3	0 41 0	.....	.....	.....	128 134	826	900
6	5	1 20 0	92 102	879	958			
5	4	1 33 30	102 110	875	954			
3	2	2 33 30	.....	.....	.....	135 139	805	877
5	4	2 54 30	.....	.....	.....	140 148	783	853
5	4	3 10 30	.....	.....	.....	149 157	765	834
4	3	3 21 0	.....	.....	.....	157 163	739	806
		October 30, 1869.						
4	3	11 40 0	113 119	899	980	164 170	837	912
6	5	11 43 0	.....	.....	.....	164 174	845	921
5	4	11 43 30	111 119	902	983			
6	5	0 0 0	120 130	899	980			
5	4	0 1 30	122 130	896	977	175 183	828	903
6	5	0 3 0	.....	.....	.....	175 185	831	906
4	3	0 17 0	131 137	905	986			
3	2	0 18 30	133 137	902	983	186 190	843	919
6	5	0 23 0	.....	.....	.....	186 196	842	918

Observations.			Mean results at Mussoorie observed with A and reduced to 32° Fahr.			Mean results at Dehra observed with B and reduced to 32° Fahr.		
In ⊙.	In ×.	Mean of the apparent times.	Nos.	In terms of A, glass *on*.	In terms of A, glass *off*.	Nos.	In terms of A, glass *on*.	In terms of A, glass *off*.
			November 1, 1869.					
4	3	11 15 0	.....	.....	.....	197 203	.....	916
3	2	11 28 30	.....	.....	.....	204 208	859	936
3	3	11 45 45	.....	.....	.....	209 214	.....	935
4	3	0 0 0	.....	.....	.....	215 221	848	924
4	3	0 15 0	.....	.....	.....	222 228	.....	932
4	3	0 30 0	.....	.....	.....	229 235	856	933
4	3	0 45 0	.....	.....	.....	236 242	.....	917
			November 3, 1869.					
3	2	11 14 30	138 142	.....	1001			
3	2	11 15 0	.....	.....	.....	243 247	.....	930
4	4	11 17 15	.....	.....	.....	243 250	.....	923
4	3	11 30 0	.....	.....	.....	251 257	842	918
3	2	11 36 30	143 147	927	1010			
4	3	11 45 0	.....	.....	.....	258 264	.....	912
4	3	11 46 0	148 154	.....	1013			
4	3	0 0 0	155 161	923	1006	265 271	833	908
4	3	0 15 0	162 168	.....	1015	272 278	.....	929
4	3	0 30 0	169 175	922	1005	279 285	848	924
4	3	0 45 0	176 182	.....	1020	286 292	.....	937
3	2	1 8 30	183 187	908	990			
3	2	1 19 30	188 192	.....	945			
3	2	1 30 30	193 197	879	958			
3	2	1 41 30	198 202	.....	973			
			November 4, 1869.					
3	2	8 3 30	203 207	777	847	293 297	659	718
6	5	8 8 0	203 213	789	860			
4	3	8 18 0	.....	.....	.....	298 304	688	750
6	5	9 8 0	214 224	862	940			
4	3	9 11 0	218 224	865	943	305 311	753	821
7	6	9 15 30	.....	.....	.....	305 317	763	832
6	5	10 8 0	225 235	914	996	318 328	804	876
7	6	10 9 30	.....	.....	.....	318 330	804	876
5	4	11 8 30	236 244	918	1001			
7	6	11 9 30	.....	.....	.....	331 343	828	903
6	5	11 10 0	236 246	917	1000			
6	5	11 11 0	.....	.....	.....	333 343	834	909
4	3	11 19 0	244 250	908	990			
5	4	0 6 30	251 259	905	986	344 352	838	913
7	6	0 9 30	251 263	906	988			
6	5	1 8 0	264 274	903	984	354 364	818	892
7	6	1 9 30	.....	.....	.....	354 366	821	895
7	6	2 9 30	.....	.....	.....	367 379	775	845
7	6	2 10 30	275 287	884	964			
7	6	3 9 30	288 300	836	911	380 392	695	758
5	4	4 6 30	301 309	720	785			
7	6	4 9 30	301 313	711	775	393 405	495	540
4	3	4 17 0	309 315	684	746			

Remarks.

	Lat. N.	Long. E.	Height, in feet, above mean sea-level.
	° ′	° ′	
Mussoorie	30 28	78 7	6937
Dehra	30 19	78 6	2229

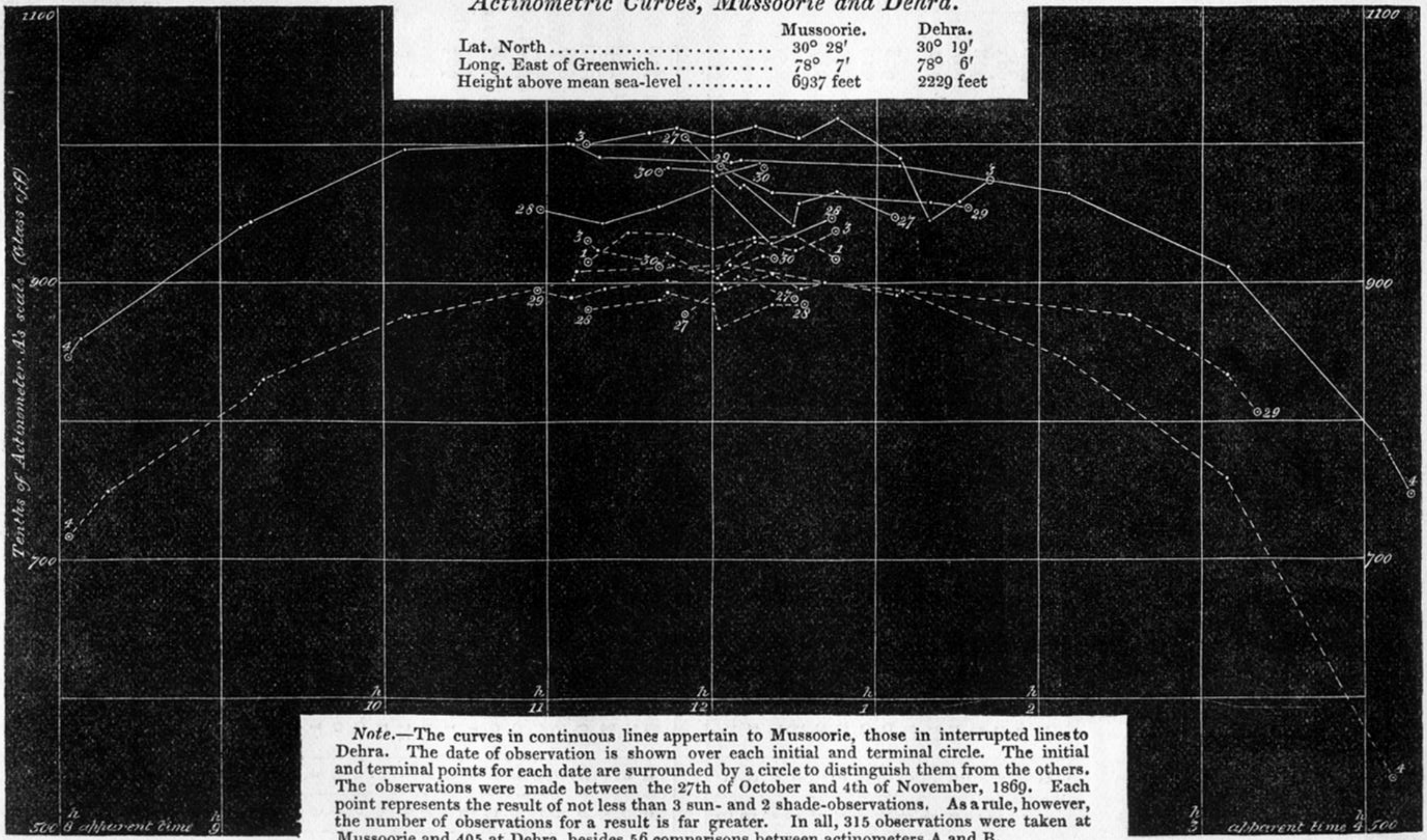


Note.—The curves in continuous lines appertain to Mussoorie, those in interrupted lines to Dehra. The date of observation is shown over each initial and terminal circle. The initial and terminal points for each date are surrounded by a circle to distinguish them from the others. The observations were made between the 27th of October and 4th of November, 1869. Each point represents the result of not less than 3 sun- and 2 shade-observations. As a rule, however, the number of observations for a result is far greater. In all, 315 observations were taken at Mussoorie and 405 at Dehra, besides 56 comparisons between actinometers A and B.

The Society then adjourned over the Christmas Recess to Thursday, January 12, 1871.

Actinometric Curves, Mussoorie and Dehra.

	Mussoorie.	Dehra.
Lat. North	30° 28′	30° 19′
Long. East of Greenwich	78° 7′	78° 6′
Height above mean sea-level	6937 feet	2229 feet



Note.—The curves in continuous lines appertain to Mussoorie, those in interrupted lines to Dehra. The date of observation is shown over each initial and terminal circle. The initial and terminal points for each date are surrounded by a circle to distinguish them from the others. The observations were made between the 27th of October and 4th of November, 1869. Each point represents the result of not less than 3 sun- and 2 shade-observations. As a rule, however, the number of observations for a result is far greater. In all, 315 observations were taken at Mussoorie and 405 at Dehra, besides 56 comparisons between actinometers A and B.