TRANSACTIONS

OF THE

ASIATIC SOCIETY.

I.

An account of Experiments made in the MYSORE COUNTRY, *in the year* 1804, *to investigate the effects of Terrestrial Refraction.*

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INTRODUCTION.

NOTWITHSTANDING the various theories which have been advanced, at different times, to account for the effects of refraction*; and the numerous experiments which have been made by the most eminent philosophers of our times, with a view to discover some law by which its effects might be reduced to certain narrow limits, applicable to practice, nothing sufficiently satisfactory has yet occurred to set the question finally to rest.

The late GENARAL ROY was the first among us, who availed himself of the favorable opportunity which his survey presented, to pay some minute at-

* Particularly by DE CARTES, LEIBNITZ, the two BERNOUILLIS, and lastly by SIR ISAAC NEWTON, whose hypothesis, grounded on the laws of attraction, now generally obtains among physical writers.

tention to the effects of terrestrial refraction. After him COLONEL WILLIAMS and Mr. DALBY resumed the investigation, as far as the service on which they were employed conveniently allowed: but as this was but a secondary object with them, little additional information is to be gathered from their labours. MAJOR MUDGE has, indeed, made a number of experiments since that time; but the result has fallen so far short of his expectations, that he promises, in his latest publication, to resume and pay particular attention to the subject: and we have no doubt every right to expect something very valuable from that quarter. But, may not the laws of refraction be so materially affected by gravity, and other unknown causes, as to vary in different parts of the globe, and that theory which obtains in high northern latitudes fail in tropical regions? indeed, the irregularities which of late have been detected in the declinations of certain stars *, which, though unobserved in *England*, are powerfully felt in these climates, sufficiently show how much we have reason to suspect an

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* MAJOR LAMBTON, in a postscript to one of his late reports to government, has this observation. "We find here, that different stars "give very different latitudes after being corrected for aberration, "nutation, &c. At *Trivandeporum*, the latitude of that station by "*Aldebaran* was 11° 44′ 52″ 59. The latitude by *Regulus* was "11° 44′ 47″ 84, and the latitude by αOrionis, 11° 44′ 40″ 91. I had "made observations by the same three stars at *Paudree* station, where "those by *Regulus* and αOrionis were often interrupted on account of "the bad weather, and consequently left doubtful: but the differences "notwithstanding were nearly the same, &c. Though these observations have been set aside, they serve sufficiently to prove that the "declinations, as laid down in *Europe*, are irregular *here*, and this "may probably arise from the uncertainty we labour under with respect to the laws of refraction; and in consequence of erring in "that, the difference of the corrected zenith distances of two stars "observed in *Europe*, will *not* be the same as the difference which "the same stars will give in this latitude. I am, however, hazarding "an opinion, but as I intend, being more satisfied as to the *fact*, I "hope I shall be able to say more on the subject hereafter."

effect of the sort, and must evince the expediency of obtaining corresponding experiments in different latitudes; for, it is obvious, that even to ascertain any deviation in a system, perhaps too generalised, might be attended with incalculable advantages to science.

It must be owned, that to render experiments on terrestrial refraction pointedly useful, it would be necessary to shew how discoveries in this province might apply and be extended to refraction in general. Hitherto, on this recondite subject, nothing which would immediately apply has reached my knowledge; but as so much is still to be done whenever refraction is concerned, we may argue, that, in the present stage of our information, observations confined to terrestrial objects may be deemed sufficient.

It has been stated on experiments*, that the refractive power of the air is proportional to its density; and this is as its weight directly, and heat inversely. It would then appear, were our barometers and thermometers sufficiently accurate, that by comparing them at any given time, the ratio of its density might be had. But it has been found, on trial, that in the present unimproved state of these instruments, changes, not very minute, in the density of the atmosphere, escape our notice, when a reference is made to them alone.

Now, since we have every reason to suppose, that whatever share, heat, cold, or electricity, may have separately on the refractive powers of the air †, their

* By Halley.

† Euler, after a number of experiments on the immediate effects of heat and cold, on the refractive powers of media, concludes, "that, "in all translucent substances, the focal distances diminish with the "heat, which diminution, he conceives, is owing to a change in the

effect is extremely inconsiderable, when compared with that caused by the bulk of water contained in dissolution in the atmosphere: we may, therefore, in the present inquiry, consider them merely as agents, composing and decomposing perpetually the air; and neglect the consideration of that immediate effect which SMITH and EULER have ascribed to them. Should we then succeed, in ascertaining, with any degree of accuracy, the relative degree of moisture and dryness, at the different times of observation, we shall (without neglecting other considerations) lay more stress on these results, than on what might be deduced separately from observations of the barometer and thermometer.

Before entering into the subject of experiments, it will be proper to preface a few words on the motives which induced me to attend particularly to the effects of terrestrial refraction, at the time that I did; as it will afford an opportunity of giving an account of the data on which I chiefly proceeded.

Having received directions from MAJOR LAMBTON *, to measure a line near *Bangalore*, to serve as a base of verification to the trigonometrical operations which were then carried on under his superintendance, it occurred to me, when this service was completed, that so favourable an opportunity was not likely to recur, for entering minutely into the subject; for every possible means had been taken, to insure as accurate a measurement as could be effected: and this line, together with the elevation of one of

" refractive power of the substance itself; which probably increases " by heat, and diminishes by cold."

But this applies chiefly to hard media, such as glass lenses, &c. &c. and may be deemed (for the present) too inconsiderable to require particular notice, where air is the medium.

* Whose assistant I then was.

its extremities above the other, (ascertained in the course of the measurement) afforded every necessary datum to proceed on in this investigation.

As the detailed account of the abovementioned operation will appear at full length in MAJOR LAMBTON's reports, and cannot with propriety be given in this paper, I hope that its being known to form a part of the trigonometrical operations, carried on in the peninsula of *India*, will appear a sufficient pledge of its accuracy.

ACCOUNT OF INSTRUMENTS.

The elevations and depressions were taken with the great theodolite, used by MAJOR LAMBTON, for carrying on his series of primary triangles across the peninsula. This instrument, having been formerly described by himself, need not be any further particularised. The angles were invariably taken with the micrometer in the focus of the telescope.

A barometer and thermometer were also procured*; but from the reasons above given, the want of an hygrometer was likely to deprive me of what I considered to be an essential means of investigation, (though I cannot find that such an instrument was ever applied to a similar purpose) when LIEUTENANT KATER, of H. M. 12th regiment, communicated to me his observation on the bearded seeds of a wild grass, called in the Malabar tongue *Panimoolca* (the *Andropogon contortum* of LINNÆUS) which grows in abundance in this part of the peninsula, and which he thought was likely to answer for an instrument of this sort †.

* The barometer was a common one, the property of Dr. HEYNE, the company's naturalist. The thermometer, one of Fahrenheit's division.

† The beards of the wild oats have been used in *England* for a similar purpose (see HUTTON's Dictionary, art. *Hygrometer*).

Although I understand it to be this gentleman's intention to give an account of his experiments on these fibres to the public; yet, as his official calls prevented him from going minutely into the subject, at the period when I had occasion for an hygrometer, I was under the necessity of anticipating his intended investigation; and the experiments detailed in the appendix will shew, that after an ample trial, the beards of the *Panimooloo* grass were found perfectly competent to the construction of an hygrometer. Three of these instruments were therefore constructed, and the mean of their readings noticed in the annexed tables.

EXPLANATION OF THE TABLES.

The detail of experiments on the effects of terrestrial refraction, together with the immediate results deduced from them, appear in these tables, under the appropriate columns; and a reference to them will best explain their arrangements.

It is however necessary to explain the meaning of certain marks, which appear at various places under the figures, and which have been adopted both for the sake of perspicuity and brevity.

I soon perceived, after collecting a certain number of observations, the prevailing agreement between the motions of the hygrometer, and the variations, which occurred in the observed angles of elevation and depression.

This being a novel and interesting fact (of which I had still more reason to be convinced, after I had succeeded in regulating the hygrometers) I was desirous to draw the attention on this coincidence, and with this view the marks alluded to were affixed.

Taking it for granted (as perhaps the present experiments will be deemed to allow) that where the moisture of the atmosphere is greatest, the refraction at that moment is also greatest (and *vice versa*) wherever, in the annexed tables, the observation rigorously agrees with this theory, the mark (§) is placed underneath*; where the coincidence of moisture and refraction is not absolutely exact, the approximation is pointed out by a cross † ‡, shewing, by the number of its bars, how near it comes to perfect consistency.

With a view to draw the attention still closer to the effects of moisture on refraction, two columns of differences, which were kept at the time of observation, have been preserved. The column which relates to the angles being marked ±, according as these have been measured greater or less, at the two nearest observations; and that of the contemporaneous relative moisture being marked M, or D, according as the atmosphere had changed from a moister to a drier state, and *vice versa*.

As this coincidence has been very general, I found

* It is to be noticed, however, that morning and evening observations are compared separately, neglecting those taken in the middle of the day; for these, from the great motion which then disturbs the atmosphere, must necessarily be very imperfect. The only reason why these observations are not left out altogether, is, that however imperfect they may be, as to a second or two, they contribute nevertheless to establish the proof of the relation of moisture to refraction; for it is to be observed, that (when the weather is perfectly clear of rainy clouds) the refraction is never so inconsiderable as in the heat of noon, when the sun shines brightest, and when the tremor of the atmosphere is most considerable; and the reason of this seems to be, "because the atmosphere, however disturbed, "is then generally in its driest state." There was so little refraction at that hour, that the elevations of the *Muntapum* frequently bring it out *negative*; an absurdity which arises both from the impossibility of taking the angles accurately, and the very small refraction then prevailing.

the shortest way was to mark with an asterisk (*) those cases where it had failed; and by inspecting the tables, it will appear that the number of these is comparatively small.

The quantity of refraction, as entered in the appropriate columns, has been computed, according to those respective cases of depression or elevation, founded on reasonings too generally known to require any minute explanation.

It will only be necessary to state, that, with regard to the measured line, the formula $r = \frac{1}{2} A - D + a$ * has been used in preference to that of $r = \frac{A-(D+D')}{2}$, for the obvious reason, that a greater reliance was to be placed on the perpendicular depression, obtained during the process of measurement, than on corresponding angular depressions, taken at the S. end of the base line, even though an equal number of observations had been taken at each end.

The refraction, affecting the elevation of the *Muntapum* †, was necessarily computed by means of the elevations and depressions, taken at both places respectively, $r = \frac{A-(D-E)}{2}$ being the appropriate formula, where E expresses the elevation, and is less than D.

An example of each will suffice to render the subject perfectly clear.

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* Where r = Refraction.
$\frac{1}{2} A$ = One half the contained arc.
D = The greater depression.
D' = The less depression.
And a = The angle subtended by the perpendicular depression of S. end of measured line.

† A small stone building, on a very conspicuous rising ground, about four miles N. of *Bangalore*.

EXAMPLE I.

The length of the measured line (*Banswary* and *Beygoor*) being converted into an arc of a great circle, gives 6′ 34,″ 67=A*.

Again, the depression of the south extremity of the line (near *Beygoor*) below the level of the northern one, is 39. 7 feet, and using the proportion of radius to tangent, we have for the angle which it subtends 3′ 25.″ 75=a.

Lastly, on the 7th of August, at 6h. 39′ A. M. the depression of the foot of the flag-staff near *Beygoor*, was observed at *Banswary*, 6′ 42″ 66.

But the height of the observer's eye above the ground was 5. 67 feet (that of the instrument) which to reduce to the ground, will require 29″·39 to subtract: consequently, the corrected depression will be 6′ 13″. 27=D (the quantity entered in the tables). Whence

$\frac{1}{2}$ A=	3′	17″	34
+ a=	3	25	75
	6	43	09
−D=	6	13	27
r=		29	82

The refraction entered in the tables.

* The horizontal length of the measured line is 39799, 31 feet; and when reduced to the level of the sea,=39793, 7. This length has been used, in this particular case, to obtain the contained arc; because the tables, by means of which the operation was performed, were calculated to that distance from the centre of the earth.

EXAMPLE II.

At the same hour, the top of the flag-staff was observed 4′ 37.″ 32; which, corrected for the height of the instrument, as above, gives the depression 4′ 07″ 93=*D*. Again, the length of the flag-staff being 24 feet, this subtracted from 39. 7, leaves the perpendicular depression below the line of the level 15. 7 feet; and the angle which it subtends=1′ 21″. 36=*a*.

Hence we have,

$\frac{1}{2}$ *A*=	3′	17″	34
+ *a*=	1	21	36
	4	38	70
− *D*=	4	7	93
r=	0	30	77

The refraction entered in the tables.

EXAMPLE III.

1st. The distance from the N. extremity of the line (*Banswary*) to the *Muntapum* is 26327. 3, which, converted into an arc of a great circle, is 4′ 18″ 7=*A*.

2d. Again, the elevation of the *Muntapum* was taken at *Banswary* (on the same day 8h 17′ A. M.) 9′ 21″ 84, and this corrected for the height of the instrument (by adding 44″ 43), makes the elevation 10′-6″ 27=*E*.

3d. Lastly, in the beginning of August, during the afternoon, being at the *Muntapum*, the depression of N. end of line was observed, on a mean of four observations, to be 15′ 19″ 5, and the instrument (in the *Muntapum*) being 8, 5 feet above the ground, we have to subtract 1′ 6″ 59, which reduces the depression to 14′ 12″ 91=*D*, a constant quantity in computing the third column of refraction.

Hence we have,

D=	14′	12″	91
—*E*=	10	06	27
	4	06	64
A=	4	18	7
2)	0	12	06
r=		06	03

The refraction entered in the tables.

The absolute degree of moisture was deduced as follows:

As I knew of no standard, by which I might set the hygrometer, when I was about observing, the least degree of moisture noticed during the day was assumed as zero. This arrangement had this advantage, that the refraction and moisture had a similar direction, and their coincidence met the eye more easily.

The column which shews the absolute density of the atmosphere was computed by this formula:

$D=(B-B')\times\frac{9600\,d}{9600}\times\overline{1-\frac{n}{435}}$ * founded on rea-

* Where *D* expresses the increase of density, *B* the height of barometer at the time of observation, *B'* the state of the same when lowest of all, *n* the difference of temperature in the air, and *d* the difference of temperature in the mercury.

sonings sufficiently known. An example, however, may not be deemed superfluous.

EXAMPLE.

The lowest degree to which the barometer descended during the course of these experiments, was 26. 85 inches$=B'$, when the temperature also least of all was 69°. These two quantities are used as constant in the computations.

Now, on the 7th of August, at 6h. 39′ A. M. the
barometer was oberved to be at 27$=B$
from which deduct 26 85$=B'$

there remains, 0 15$=B-B'$

Again, the thermometer at the same time
was 75°
from which deduct 69

and we have 6$=n$; and as no difference of temperature was noticed in the atmosphere and mercury, the same quantity (6) will also be expressed by d.

Hence it is that having found, $B-B'=0.\ 15$; $\frac{9600-d}{9600}=0.\ 99$, &c.; and $\frac{435-n}{435}=0.\ 98$, &c. we have $0.\ 15\times 0.\ 99\times 0.\ 98=0.\ 145530$; which to reduce in terms of B (the least density) we have $\frac{26\ 85}{0\cdot145530}=\frac{1}{184}$ the increase of density.

Lastly, to obtain an expression in absolute numbers, we have, as $26.\ 85 : 26.\ 85+\frac{1}{184} :: 1000 : 1000.\ 202$, the quantity entered in the tables.

The remaining columns are sufficiently explicit to require no explanation.

	Sun shining: great motion in the atmosphere.
	Ditto, ditto.
1/53 34	Sun shining.
1/58 13	Motion in the atmosphere moderate: flag extremely faint.
1/23 20	Sun shining: cloudy.
1/18 69	Hygrometers very unsteady.
1/19 13	Sun shining.
1/13 13	Cloudy.
1/19 13	Ditto.
1/24 04	Cloudy: sun shining.
1/79 11	Ditto, ditto.
1/104 31	Cloudy: sun shining: motion in the atmosphere.
1/215 58	Flag extremely faint: sun shining.
	Motion in the atmosphere: light clouds.
	Sun shining: cloudy.
1/34 00	Cloudy.
1/18 69	Ditto.
1/13 13	Sun shining: cloudy.

small; and from this inaccuracy, a result equally defective

Month and days.	Time of observation.	Number of ditto.	Barometer.	Thermometer.	Depression of Foot of Flag-Staff, S. E.				
					Depressions reduced.	Difference.	Difference of moisture and dryness.	Absolute degree of moisture.	Increase or decrease of density

Month and days.	Time of observation.	Number of ditto.	Barometer.	Thermometer.	Depression of. Depressions reduced.		Elevation of. Elevations reduced.	Difference.	Difference of
13th.	6	1	27 05	71	5—53 53 §	07	10 27 55 §		
	7 45	2	27 05	72	6—20 37 §	02	10 15 73	—11	8D
	9	3	27 05	73		17	10 04 70	—11	0D
	9 45	4	27	75		56	9 56 03 §	— 8	D
	11	5	27	79			9 42 40	—13	D
	12	6	27	79			10 03 12	+20	M
	2	7	27	83			9 39 48	—23	D
	4	8	27	85	6—19 57 §	1	8 45 90 §	—54	D
	5 10	9	27	84	6—10 09	5	10 19 67	+33	I
	5 30	10	26 85	84	6—03 03	0	10 21 25	+ 1	(
	6	11	26 9	82	5—48 85 §	1	10 30 70 §	+ 8	I
14th.	6	1	26 95	70		3	10 21 25 §		
	8 30	2	26 95	73	5—48 85 §	7	10 09 43	—11	1
	9 12	3	26 95	76	6—48 63 §	4	10 03 91 §	— 5	
	10	4	27	76			9 48 15	—15	
	12	5	27	83			8 45 00	—	11
	2	6	26 9	84			9 56 82		17
	2 25	7	26 9	85			9 54 45	—	2
	3	8	26 9	85			9 59 18 §	+	1
	4	9	26 9	84	6—25 87 §	1	10 00 76	+	
	5 30	10	26 9	83	6—10 91	7	10 22 83	+	
	5 30	11	27	81	6—04 63	5	10 27 55	+	7
	6	12	26 95	81	5—55 15 §	7	10 25 91 +	—	1
15th.	6	1	27	69		3	10 22 83 §		
	7	2	27	71		7	10 14 15	—	11
	8	3	27	73		5	10 08 64	—	70
	9	4	27	75		1	10 03 12	—	50

Month and days.	Time of observation.	Number of do.	Barometer.	Thermometer.	Depression of Foot of Flag-staff S. Ext. of Line. Depressions reduced.	Difference.	Difference of moisture and dryness.	Absolute degree of moisture.	Increase or decrease of density in the air.	Refraction.	Depression of top of Flag-staff S. Ext. of Line. Depressions reduced.	Difference.	Difference of moisture and dryness.	Absolute degree of moisture.	Increase or decrease of density in the air.	Refraction.	Elevation of Foot of Muntapun. Elevations reduced.	Difference.	Difference of moisture and dryness.	Absolute degree of moisture.	Increase or decrease of density in the air.	Refraction.	Refractions compared. Foot of flag staff + than top.	Foot of flag staff + than Muntapun.	Top of flag staff + than Muntapun.	Ratio of refraction to the contained arc. Foot of flag staff.	Top of flag staff.	Muntapun.	REMARKS.
13th.	6	1	27 05	71	5—53 53	+ 26 84	D 82	496	1000 271	49 56	4—1 63	+ 11 04	D 82	496	1000 271	37 07	10 27 55	—11 82	D 82	496	1000 271	16 67	+ 12 49	+ 32 89	+ 20 40	1/7 96	1/10 64	1/15 51	Cloudy.
	7 45	2	27 05	72	6—20 37			414	1000 271	12 72	4—12 67	+ 16 56	D 167	414	1000 271	26 02	10 15 73	—11 03	D 167	414	1000 271	10 76	— 3 26	11 96	15 27	1/17 37	1/15 16	1/24 04	Slight motion in the atmosphere.
	9	3	27 05	73							4—27 23	+ 7 91	D 42	247	1000 271	9 47	10 04 70	— 8 62	D 42	247	1000 271	5 24			4 23		1/41 67	1/49 37	Motion in the atmosphere.
	9 45	4	27	75							5—37 14			205	1000 202	1 66	9 56 03	—13 63	D 70	205	1000 202	0 91			0 65		1/252 99	1/284 28	Flag very faint: great motion in the atmosphere.
	11	5	27	79													9 42 40	+ 20 8	M 15	135	1000 202	Negative.							Sun shining.
	12	6	27	79													10 03 12	—23 72	D 95	150	1000 202	4 46						1/58 00	Motion in the atmosphere considerable: sun shining.
	2	7	27	83													9 39 48	—54 58	D 55	55	1000 202	Negt.							Sun shining bright: light clouds.
	4	8	27	85	6—19 57	—9 48	M 15	0	1000 202	23 52	4—14 29	—13 44	M 15	0	1000 202	24 41	8 45 90	+ 33 77	M 15	0	1000 202	Negt.	— 0 89			1/16 78	1/16 16		Hazy light clouds: motion in the atmosphere abated.
	5 10	9	27	84	6—10 09	—7 06	0	15	1000 202	33 00	4—00 85	— 7 05	0	15	1000 202	37 85	10 19 67	+ 1 58	0	15	1000 202	12 74	— 4 85	20 26	25 11	1/17 96	1/10 42	1/20 31	Motion in the air much abated.
	5 30	10	26 85	84	6—03 03	—14 18	M 15	15	1000	40 06	3—53 80	— 6 36	M 15	15	1000	44 90	10 21 25	+ 8 45	M 15	15	1000	13 52	— 3 84	26 54	32 39	1/9 85	1/8 78	1/19 13	Sun shining: atmosphere very still.
	6	11	26 9	82	5—48 85			30	1000 065	51 24	3—47 49			30	1000 065	57 21	10 30 70			30	1000 065	18 24	— 5 97	33	38 97	1/7 70	1/6 89	1/14 19	Sun shining.
14th.	6	1	26 95	70							3—42 77	+ 28 36	D 134	507	1000 131	55 93	10 21 25	—11 82	D 134	507	1000 131	13 52			42 41	1/13 74	1/7 05	1/19 33	Sun shining occasionally: flag very faint.
	8 30	2	26 95	73	5—48 85	+ 19 78	D 7	373	1000 131	54 24	4—11 13	+ 22 86	D 7	373	1000 131	27 57	10 09 43	— 5 52	D 7	373	1000 131	07 61	+ 6 67	47 63	19 96	1/7 27	1/14 31	1/34 00	Flag very faint: sun shining.
	9 12	3	26 95	76	6—48 63			366	1000 131	38 46	4—33 99			366	1000 131	4 71	10 03 91	—15 76	D 4	366	1000 131	4 85	+ 33 75	83 61	0 14	1/12 26	1/84 79	1/53 34	Sun shining.
	10	4	27	76													9 48 15	— 3 15	D 110	324	1000 202	Negt.							Great motion in the atmosphere: sun shining.
	12	5	27	83													8 45 00		D 175	214	1000 202	Negt.							Ditto ditto.
	2	6	26 9	84													9 56 82	— 2 37	D 27	39	1000 065	1 30						1/199	Sun shining.
	2 25	7	26 9	85													9 54 45	+ 4 73	D 12	12	1000 065	0 12						1/215 58	Motion in the atmosphere.
	3	8	26 9	85													9 59 18	+ 1 58	M 2	0	1000 065	2 48						1/104 31	Ditto ditto.
	4	9	26 9	84	6—25 87	—14 96	M 7	2	1000 065	17 22	4—27 69	—29 96	M 7	2	1000 065	11 01	10 00 76	+ 22 07	M 7	2	1000 065	3 27	+ 6 21	13 95	7 74	1/22 90	1/35 84	1/79 11	Light clouds.
	5 30	10	26 9	83	6—10 91	—6 28	M 71	9	1000 131	32 18	3—57 73	— 7 08	M 71	9	1000 131	40 97	10 22 83	+ 4 72	M 71	9	1000 131	14 31	— 7 79	17 87	26 65	1/12 26	1/9 63	1/18 07	Ditto ditto.
	5 30	11	27	81	6—04 61	—9 48	M 12	80	1000 202	38 46	3—50 65	— 1 62	M 12	80	1000 202	18 05	10 27 55	— 1 58	M 12	80	1000 202	16 67	— 9 59	21 79	31 40	1/10 26	1/8 21	1/15 52	Ditto ditto.
	6	12	26 95	81	5—55 15			92	1000 131	17 94	3—49 03			92	1000 131	49 67	10 25 91			92	1000 131	15 88	— 1 73	32 06	33 79	1/8 23	1/7 94	1/16 29	Ditto ditto.
15th.	6	1	27	69							3—56 17	+ 1 50	D 112	450	1000 202	12 53	10 22 83	— 8 68	D 115	459	1000 202	14 31			28 22		1/9 28	1/18 07	Cloudy.
	7	2	27	71							1—57 83	18 12	D 70	34	1000 202	10 97	10 14 15	— 5 52	D 70	347	1000 202	9 97			31 00		1/9 63	1/25 94	Ditto.
	8	3	27	73							1—15 85	+ 11 85	D 50	277	1000 202	2 85	10 08 65	— 5 52	D 5	277	1000 202	7 21			15 64		1/17 27	1/35 88	Sun shining: cloudy.
	9	4	27	75							1—27 69	+ 6 3	D 32	227	1000 202	11 02	10 03 12	—12 61	D 32	227	1000 202	4 45			6 56		1/35 84	1/58 13	Cloudy: sun shining: motion in the atmosphere.
	11	5	27 05	76							1—33 99			1	1000 27	4 71	9 50 5	0 79	M 27	195	1000 271	Negt.					1/83 79		Sun shining: great motion in the atmosphere.
	12	6	27	81													9 51 30	+ 12 61	D 142	227	1000 202	Negt.							Ditto ditto.
	12 45	7	27	82													10 03 91	0 79	D 7	80	1000 202	4 85						1/53 34	Sun shining.
	2	8	26 95	84							1—83 99	—24 58	0		1000 131	4 71	10 03 12	— 13 49	0	5	1000 131	4 45			0 26		1/83 79	1/58 13	Motion in the atmosphere moderate: flag extremely faint.
	4	9	26 95	83	6—10 91	+ 5 48	D 5	5	1000 131	32 18	1—9 41	— 3 24	D 5	5	1000 131	29 29	10 16 5	5 51	D 5	5	1000 131	11 15	+ 2 89	21 03	18 14	1/12 26	1/13 47	1/23 20	Sun shining: cloudy.
	5	10	26 9	82	6—16 39	—2 34	M 14	0	1000 065	26 70	3—56 17	— 0 79	M 14	0	1000 065	12 51	10 22 05	— 0 78	M 14	0	1000 065	13 91	—15 89	12 79	26 62	1/14 77	1/9 28	1/18 69	Hygrometers very unsteady.
	6 35	11	26 95	32	6—14 05	—3 14	M 20	14	1000 065	29 04	3—55 88	— 4 73	M 20	14	1000 065	13 35	10 21 25	+ 12 36	M 110	14	1000 065	13 52	—14 28	15 52	29 80	1/13 58	1/9 11	1/19 13	Sun shining.
	6	12	27 05	81	6—10 91			34	1000 271	31 18	3—50 65			34	1000 271	48 05	10 33 61			34	1000 271	19 70	—15 87	12 48	38 35	1/12 26	1/8 21	1/13 13	Cloudy.
16th.	6	1	27	71	6—6 97	+ 14 24	D 27	687	1000 202	36 12	3—51 41	+ 17 97	D 27	687	1000 202	47 26	10 21 25	— 5 62	D 27	687	1000 202	13 52	—11 14	22 60	33 74	1/10 92	1/8 35	1/19 13	Dittos
	7	2	27	72	6—24 21			660	1000 202	14 88	1—09 50	+ 0 14	D 60	660	1000 202	29 29	10 15 73	+ 4 97	D 50	660	1000 271	10 76	—14 41	4 12	18 53	1/26 52	1/13 47	1/24 04	Cloudy: sun shining.
	8	1	27 05	74							1—09 55	+ 12 60	D 190	610	1000 271	29 15	10 00 76	— 1 58	D 190	610	1000 271	3 27			25 88		1/13 54	1/79 11	Ditto ditto.
	9	4	27 05	78							1—22 15	+ 7 90	D 80	420	1000 271	16 53	9 59 18	— 4 68	D 80	420	1000 271	2 48			14 05		1/23 87	1/104 31	Cloudy: sun shining: motion in the atmosphere.
	10	5	27 05	78							1—30 05			340	1000 271	8 05	9 54 45	— 6 30	D 210	340	1000 271	0 12			8 53		1/45 63	1/215 58	Flag extremely faint: sun shining.
	12	6	27	81													9 48 15	— 5 50	D 65	130	1000 202	Negt.							Motion in the atmosphere: light clouds.
	2	7	27	84													9 42 65	+ 28 78	D 65	65	1000 202	Negt.							Sun shining: cloudy.
	4	8	26 95	83	6—10 91	+ 45 83	M 05	0	1000 131	32 18	4—08 85	—11 90	M 95	0	1000 131	17 25	10 09 43	+ 12 60	M 95	0	1000 131	7 61	— 5 07	24 51	29 65	1/12 26	1/10 59	1/34 00	Cloudy.
	5	9	26 95	82	6—56 74	—3 21	M 10	95	1000 131	16 35	3—56 95	—10 24	M 10	95	1000 131	41 75	10 22 03	+ 11 58	M 10	95	1000 131	13 91	+ 4 60	32 44	27 74	1/8 52	1/9 45	1/18 69	Ditto.
	6	10	26 95	81	5—52 53			105	1000 131	19 56	3—46 51			105	1000 131	51 99	10 33 61			105	1000 131	19 70	— 2 43	29 80	32 29		1/7 38	1/13 13	Sun shining: cloudy.

N. B. Where the refraction is said to be negative, as frequently occurs in observations of the Muntapun, it is only meant to state, that, from various causes, the angle of elevation was taken too small; and from this inaccuracy, a result equally defective has ensued. These observations have been preserved, as an instance of the very small quantity of refraction, prevailing, at the time when they were taken.

Table of Experiments to Investigate the Effects of Terrestrial Refraction.

Month and days.	Time of observation.	Number of do.	Barometer.	Thermometer.	Depression of Foot of Flag-staff S. Ext. of Line. Depressions reduced.	Difference.	Difference of moisture and dryness.	Absolute degree of moisture.	Increase or decrease of density in the air.	Refraction.	Depression of top of Flag-staff S. Ext of Line. Depressions reduced.	Difference.	Difference of moisture and dryness.	Absolute degree of moisture.	Increase or decrease of density in the air.	Refraction.	Elevation of Foot of Muntapun. Depressions reduced.	Difference.	Difference of moisture and dryness.	Absolute degree of moisture.	Increase or decrease of density in the air.	Refraction.	Refractions compared. Foot of flag staff +/− than top.	Foot of flag staff +/− than Muntapun.	Top of flag staff +/− than muntapun.	Ratio of refraction to the contained arc. Foot of flag staff.	Top of flag staff.	Muntapun.	REMARKS.
7th.	6 39	1	27	75	6—13 27 §	+ 14 94	D 85	345 §	1000 202	29 82 §	4—07 93	+ 6 36	D 85	34	1000 20	30 77							− 0 96			1/13 24	1/12 82		Sun shining.
	6 54	2	27	75	6—28 21	− 7 86	D 54	260	1000 202	14 83 §	4—14 29	− 8 70	D 54	260	1000 201	24 41							− 9 54			1/26 58	1/16 16		Ditto ditto.
	7 26	3	27	74	6—20 35 +			206 +	1000 202	12 74 +	4—05 59 ‡	+ 22 08	D 43	206 ‡	1000 202	33 11 ‡							−10 38		—	1/17 35	1/11 91		Ditto ditto.
	8 17	4	27 05	73							4—27 67 §	− 7 08	M 61	163 §	1000 271	11 03	10 6 27	−18 22	M 61	163	1000 271	6 03			+ 5 00		1/35 75	1/42 83	Ditto ditto: a good deal of motion in the atmosphere.
	10 37	5	27 05	76							4—20 59	+ 9 42	D 195	224	1000 271	18 1	9 48 05	+ 8 26	D 195	224	1000 271	Negative.	}				1/21 78		Ditto ditto: great motion in the air; flag very indistinct.
	11 10	6	27	80							4—30 01	−11 82	M 93	29	1000 202	08 70	9 56 31	+ 5 12	M 93	29	1000 202	1 06			7 70		1/45 36	1/244 05	Light clouds: flag very indistinct.
	2 8	7	26 9	84							4—18 19	+ 3 96	D 21	122	1000 065	20 51	10 01 43	−10 44	D 21	122	1000 065	3 61			16 91		1/19 23	1/71 66	Light clouds: sun shining occasionally.
	4 8	8	26 9	85							4—22 15	−16 44	D 48	101	1000 065	16 55	9 50 99	+ 12 78	D 45	101	1000 065	Negt.					1/23 83		Ditto ditto.
	4 25	9	26 9	85	6—28 75	+ 1 86	D 38	53	1000 065	14 34	4—05 71	+ 4 62	D 38	53	1000 065	33 00	10 03 77	− 3 90	D 38	53	1000 065	4 79	−18 66	+ 9 55	28 31	1/27 52	1/11 96	1/54 01	Sun shining.
	4 51	10	26 9	83 5	6—30 61	+ 0 78	D 15	15	1000 065	12 48	4—10 33	+ 7 86	D 15	15	1000 065	28 37	9 59 87 +	+ 1 56	D 15	15 +	1000 065	2 83 +	−15 90	9 65	25 55	1/31 62	1/13 90	1/91 41	Sun shining.
	5 7	11	26 9	84	6—31 39 §	− 2 82	M 70	0 §	1000 065	11 70 §	4—18 19 §	−7 2	M 70	0 §	1000 065	20 51 §	10 1 45	− 5 50	M 70	0	1000 065	3 61	− 8 82	8 09	16 91	1/33 73	1/19 23	1/71 66	Sun shining: light clouds.
	5 25	12	26 95	83	6—19 57	−11 04	M 110	70	1000 131	23 52	4—11 17	−15 00	M 110	70	1000 131	27 53	10 6 93	+ 11 74	M 110	70	1000 131	6 26	− 4 02	19 16	21 18	1/16 77	1/14 33	1/40 67	Ditto ditto.
	5 37	13	26 95	81	6—08 53	+ 0 78	M 33	180 +	1000 131	34 56 +	3—56 17 +	+ 13 56	M 33	180 +	1000 131	42 53 +	10 18 67	+ 0 88	M 33	180	1000 131	12 23	− 7 98	22 33	30 31	1/11 41	1/9 87	1/21 15	Ditto ditto.
	6 3	14	26 95	80	6—09 31			213	1000 131	33 78	4—09 73			213	1000 131	30 77	10 19 55			213 §	1000 131	12 67 §	+ 3 00	21 11	18 11	1/11 68	1/12 82	1/20 41	Ditto ditto.
8th.	5 55	1	26 9	70	6—00 67	−0 24	D 52	365 +	1000 065	42 42 +							10 26 25	− 2 74	D 52	365	1000 065	16 02	—	26 40		1/9 38		1/16 15	Hazy.
	6 20	2	26 9	69	5—59 83 +	+ 6 30	D 35	313	1000 065	13 26	3—41 83 +	+ 15 12	D 35	313 +	1000 065	56 87 +	10 23 51	0	D 35	313	1000 065	14 65	−13 62	29 61	42 23	1/9 12	1/6 93	1/17 66	Ditto.
	6 58	3	26 9	69	6—06 13	+ 26 04	M 45	278	1000 065	36 96	3—56 95	+ 13 38	M 45	278	1000 065	41 77	10 23 51	− 7 92	M 45	278	1000 065	14 65	− 4 80	22 31	27 11	1/10 68	1/9 45	1/17 66	Sun shining.
	8	4	26 95	70	6—32 17	+ 6 30	D 138	323	1000 131	10 92	4—10 33	− 4 62	D 138	323	1000 065	18 37	10 15 59	−10 26	D 138	323	1000 065	10 69	−17 46	0 26	13 19	1/36 14	1/13 90	1/24 20	Sun shining: slight motion in the atmosphere.
	9	5	26 95	73	6—25 87 +			185 +	1000 131	17 22 +	4—05 71	+ 15 66	D 185	185	1000 131	33 90	10 05 33	− 9 42	D 185	185	1000 131	5 56	−15 78	11 66	27 44	1/22 92	1/54 01	1/46 58	Ditto ditto.
	10	6	26 95	75							4—21 37 §	− 5 58	M 88	0 §	1000 131	17 33 §	9 55 91	− 4 92	M 70	0	1000 131	0 85			16 49		1/22 76	1/304 35	Cloudy: great motion in the air.
	12	7	26 9	79							4—15 79	− 5 46	M 12	88	1000 131	22 93	9 50 99	+ 12 78	M 12	88	1000 131	Negt.					1/17 21		Sun shining occasionally: motion of the air very great.
	2	8	26 88	78							4—10 33			100	1000 065	18 37	10 3 77			100	1000 131	4 78			23 60		1/13 90	1/54 01	Light showers.
9th.	7 15	1	26 88	69							3—54 55	+ 10 26	D 123	211	1000 039	44 15											1/8 93		Ditto ditto.
	9	2	26 88	69	6—08 55 +	+ 11 81	D 81	81 +	1000 039	34 56 +	4—04 81	+ 9 48	D 81	81	1000 039	33 89	10 25 51	− 6 36	D 81	81	1000 039	14 65	+	19 91	16 25	1/11 41	1/11 64	1/17 66	Cloudy and hazy.
	10 12	3	26 9	70	6—20 35 +	+ 14 16	M 315	0	1000 065	22 74 +	4—14 29 §	− 7 92	M 315	0 §	1000 039	24 41 §	10 17 15 §	+ 2 40	M 315	0 §	1000 039	11 47 §	− 1 68	11 27	12 29	1/17 35	1/16 16	1/22 55	Flag very faint.
	12	4	26 9	72	6—31 51	−19 12	D 225	315	1000 065	08 58	4—06 37 +			315 +	1000 039	32 33 +	10 19 55	− 7 86	D 225	315	1000 039	12 67	−23 76	− 4 09	19 77	1/46 00	1/12 21	1/20 41	Cloudy: hygrometers very unsteady.
	2	5	25 85	69	6—16 39	+ 4 16	0	90	1000	26 70							10 11 69	− 0 84	0	90	1000	8 74		+ 17 9		1/14 77		1/29 60	Heavy clouds: hygrometers very unsteady.
	4	6	26 9	75	6—10 35	−15 78	M 28	90	1000 065	12 74 §							10 10 85	+ 12 66	M 27	90 +	1000 065	32		14 42		1/17 35		1/31 09	Ditto ditto.
	5	7	26 9	73	6—04 57	− 9 42	M 128	367	1000 065	18 52							10 23 51	+ 4 68	M 128	367	1000 065	11 60		23 89		1/10 24		1/18 43	Light showers.
	5 45	8	26 9	73	5—55 15	+ 5 42	M 15	495	1000 065	17 94							10 28 19	−17 58	M 15	495	1000 065	16 97		31 96		1/8 23		1/15 23	Cloudy.
	6	9	27	72	6—00 67 +			510 +	1000 202	42 42 +							10 10 61			510 §	1000 202	8 21		34 21		1/9 30		1/31 51	Cloudy.
11th.	6	1	27	68	5—53 53	+ 22 86	D 248	256	1000 202	19 56	3—50 65 §	+ 4 94	D 248	256 §	1000 202	48 05 §	10 19 67 §	− 7 89	D 248	256 §	1000 202	10 74 §	+ 1 51	36 82	35 41	1/7 96	1/8 19	1/20 31	Foggy: sun shining occasionally.
	8	2	27	70	6—16 39	+ 9 26	D 28	28	1000 202	26 70	4—05 59	+ 10 26	D 25	28	1000 202	33 11	10 11 79	− 4 73	D 28	28	1000 202	[illegible] 79	− 6 41	17 91	24 42	1/14 78	1/11 93	1/29 43	Sun shining: hygrometers extremely unsteady.
	9 33	3	27 05	73	6—26 65	− 7 86	M 232	0	1000 271	16 44	4—15 85 §	0	M 232	0 §	1000 271	22 85 §	10 07 06 §	+ 2 37	M 232	0 §	1000 271	6 43 §	− 6 44	10 01	16 42	1/24 00	1/17 27	1/40 43	Ditto ditto.
	10 37	4	27 05	75	6—18 79	+ 20 89	D 168	232	1000 271	24 30	4—15 85 +	+ 10 26	D 168	232 +	1000 271	22 85 +	10 09 45	− 7 10	D 168	232	1000 271	7 61	+ 1 45	16 69	15 24	1/16 23	1/7 27		Cloudy: a good deal of motion in the atmosphere.
	12	5	27 05	76	6—39 68			64	1000 271	3 41	4—26 11	+ 2 34	D 30	64	1000 271	12 59	10 02 33	−14 18	D 30	64	1000 271	4 06	− 9 18	− 0 65	8 51	1/115 73	1/31 34	1/63 71	Motion in the atmosphere moderate.
	2	6	27	81						13 26	4—28 45 §	−18 12	M 102	34 §	1000 202	10 25 §	9 48 15	+ 20 49	M 102	34	1000 202	Negt.	+ 3 01			1/29 76	1/38 50		Motion in the atmosphere very considerable.
	4	7	27	81	6—19 83	−21 32	M 180	136	1000 202	13 26	4—10 33 ‡			136 ‡	1000 202	18 37 ‡	10 08 61 §	+ 14 18	M 80	136 §	1000 202	7 22 §	−15 11	+ 6 04	21 15	1/29 76	1/13 91	1/35 83	Motion in the air a little abated: squalls.
	5 33	8	27	76	6—08 51			316	1000 202	14 58							10 22 82 §	− 1 34		316 §	1000 202	14 31 §		20 27		1/11 91		1/18 07	Squalls all about: atmosphere very still.
12th.	6 40	1	27	69	6—03 03	+ 3 94	0	412	1000 202	10 06	4—30 85 §	+ 2 40	0	412 §	1000 202	37 85 §	10 20 48 §	− 0 81		412 §	1000 202	13 13 §	+ 2 21	26 93	24 72	1/9 85	1/10 42	1/19 70	Atmosphere very still. Cloudy.
	7	2	27 05	69	6—06 97			412	1000 271	16 12	4—03 25	+ 14 66	D 42	412	1000 271	15 45	10 19 67	− 4 30	D 42	412	1000 271	12 74	+ 0 67	23 36	28 71	1/10 92	1/21 10	1/20 31	Ditto ditto.
	9	3	27 05	71							4—17 41	+ 5 04	D 255	370	1000 271	21 29	10 13 37	−17 34	D 255	370	1000 271	9 08			12 21		1/18 53	1/28 48	Ditto ditto.
	10	4	27 05	73							4—22 45 §	− 8 16	M 85	115 §	1000 271	10 25 §	9 56 03 §	+ 12 60	M 85	115 §	1000 271	0 91 §			9 31		1/38 50	1/284 28	Great motion in the atmosphere.
	12	5	27 05	76							4—14 29	+ 11 64	D 120	200	1000 271	24 41	10 08 63	−12 60	D 120	200	1000 271	2 22			22 19		1/16 16	1/116 53	Ditto ditto ditto.
	2	6	27	81 5							4—22 93	−13 38	D 80	80	1000 202	15 77	9 56 03	+ 17 27	D 80	80	1000 202	0 91			14 86		1/25 02	1/284 28	Motion of the atmosphere very great.
	4	7	27 95	82	6—32 98	−17 34	M 70	0	1000 131	10 11	4—09 55 §	0	M 70	0 §	1000 131	19 15 §	10 13 37 §	+ 6 30	M 70	0 §	1000 131	9 09 §	19 04	1 03	20 07	1/39 03	1/13 53	1/28 45	Squalls all about: sun shining occasionally.
	5	8	27	79	6—15 64	−12 61	M 180	70	1000 202	27 45	4—09 55	−11 82	M 180	70	1000 202	29 1	10 19 67	+ 7 88	M 180	70	1000 202	12 74	− 1 70	14 71	16 41	1/14 37	1/13 53	1/20 31	Ditto ditto.
	6	9	27	78	6—03 03			250	1000 202	10 06	4—57 73			250	1000 202	10 79	10 27 55			250	1000 202	[illegible] 67	− 0 91	23 39	24 30	1/9 85	1/9 63	1/15 51	Atmosphere very still heavy; clouds all about.

REMARKS ON THE RESULTS.

1st. The most remarkable fact, which calls for our attention, in the results of the present experiments, is the almost invariable coincidence of the increase of refraction with that of moisture; which will appear still more forcibly, if we consider the results of the following eight observations, all taken between 10 and 12 o'clock, P. M. on different nights, when I was engaged in observing the eastern elongation of the polar star; the depression of the S. extremity of the line being taken by means of a referring lamp.

Days.	Depressions.			Refraction.		
Augt.						
7	5′	17″	33	1′	25″	76
10	5	36	24	1	6	85
11	5	40	18	1	2	91
12	5	49	64	0	53	45
13	5	51	21	0	51	88
14	5	54	36	0	48	72
15	5	23	63	1	19	46
16	5	40	97	1	2	12

Mean refraction 1′ 1″ 38.

On comparing the hygrometers, as they stood at the time of these observations, with their position when last noticed in the day time, it was found that they had revolved, on a mean, 240° in the direction of moisture. Now, the mean refraction of 55 observations, noticed in the tables, is 29″ 74; and we have seen that of the 8 observations taken at night (which, from the stillness of the air, may be deemed to balance a superior number) to be 1′ 1″ 38. Hence, it will appear, that the latter is something more than double the former.

2d. We shall next advert to the comparative quantity of refraction, which seems to have affected the observations of the different objects referred to in the tables; and here, it is perhaps worthy of notice, that out of 49 contemporaneous observations, of the top and foot of the flag-staff, at the S. extremity of the line, the refraction attending those of the foot are 36 repeated times *less* than those of the top; and that, in the 13 remaining ones, where the contrary occurs, the excess is seldom above 2″ of refraction, and frequently below unity *. As this circumstance is in opposition to the general theory, "that the lower the object, the greater the refraction," should the same circumstance occur again, in future experiments, it will be worth while to inquire, whether the rays, when passing through the atmosphere below the line of the level, may not be refracted differently from what they are when passing above it. This may perhaps be thought better than a mere conjecture, if it be recollected, that Mr. Bouguer, (whilst employed in measuring a degree of the meridian in *South America*, and observing on the summit of the *Cordeliers*) noticed a sudden increase of refraction, when he could view the stars below the line of the level.

3d. With regard to any attempt towards estimating the effects of terrestrial refraction, by an assumed ratio to the contained arc, as has been hitherto the practice; without entering into any discussion of the subject, I shall only observe, that if, in the foregoing experiments, we go by the observations taken in the day time, we shall have (considering the foot of flag-staff, and preserving the same notation) $r = \frac{1}{13 \cdot 27}$;

* The mean difference of refraction, between the top of the flag-staff and the *Muntapum*, (on 38 contemporaneous observations) is 16″. 44; and that between the top of flag and *Muntapum* is 22″. 51, where the order is inverted by 6″. 07: and if the top and foot of flag-staff be compared, in an equal and contemporaneous number of observations, the mean of their difference is 6″. 08 likewise in the inverse order.

and if we take those by night, it will be $r = \frac{1}{6.42}$ of the contained arc, from which we can collect nothing.

4th. I have now only to add a few words on the comparative density of the air, at the different times of observation, such as entered in the tables; and the evident want of connection, between its changes and those in the refraction; from which we may infer, that, although in northern climates (where the mercury will rise and fall several inches in one day) observations of the barometer and thermometer may be attended to with advantage, on the contrary, in tropical countries, where (as appears in the present experiments) the variations of the mercury are hardly discernible*, those instruments will prove perfectly inefficient.

APPENDIX.

An account of Experiments on the fibres or beards of the Panimooloo *grass; containing also an account of the construction of the hygrometers, used in the preceding Experiments.*

Before I proceed to give an account of the experiments, by means of which I satisfied myself of the competency of the beards of the *Panimooloo* grass, to the object I had in view, it will be necesary to give a short description of the plant itself, or (since a botanical account of it is not here intended) of that part of the plant, which was used in the construction

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* At Madras, the greatest alteration was observed 0.75 inches: and in the mean annual change 0.53. At *Banswary*, during the time of attending to the present experiments (that is about twelve days) the greatest change was 0.2: the latter place being 2970.8 feet above the level of the sea.

of the hygrometers, consulted in the preceding experiments on refraction.

The *Panimooloo* grass, which grows chiefly on mountains, and is well known to the natives, from its beards easily catching and adhering to their clothes, produces a kind of ear, somewhat resembling that of wheat. Its seed vessels shoot out long fibres, of a hardy texture, which entwist one with the other from left to right, so as to resemble, when in that state, a diminutive coir rope.

These fibres, or beards, are the part of the plant used in the construction of the hygrometers, and consequently deserve particular notice.

Each fibre shoots out, in a straight line, nearly to the length of an inch, from the seed vessel to which it adheres; then tapers off, in curls, to a very fine end, so that the former part of it can alone be used for the present purpose.

When viewed through a magnifying glass, it appears to be made up, like a rope, in broad strands, twisted from left to right; which, when water is applied (contrary to its effect on a rope) are gradually unfolded, and cause the motion of which I availed myself.

The twists, in the straight part of the stem, are from 5 to 7 in number; and these, as I have found by experiments, nearly mark the number of revolutions, of which the fibre is susceptible, by the application of moisture.

When dissected, the stem was found to be made up of two fibres, connected by a slight membrane, easily divided, and twisted round each other, until they were united in a common stalk, at the seed vessel at one end, and above the first curl at the other.

This construction readily explains why it should be easily affected by either moisture or dryness, but does not evince that heat, or other changes in the ambient air, might not likewise operate upon it in the same direction. The following experiments satisfied me, however, that moisture alone unfolded the stem.

EXPERIMENT I.

Having fixed a stem, about an inch long, with six twists in it, on a piece of wax, a slit straw was fastened at its upper end, by way of index: the whole was then placed clear of any motion of the air, in such a position as the nature of the experiments required; and a graduated circle of pasteboard was so placed about it, as to indicate the number of revolutions and degrees which the index went over.

Then, on placing my hand within an inch of the stem, the index generally moved from 5° to 10° of the circle, from *left* to *right;* and as *motion* in this direction was invariably the consequence of moisture, it was probable (but still it remained to be proved) that the *effluvia* arising from perspiration principally affected it in this case.

EXPERIMENT II.

By breathing violently on the stem, I generally brought the index round from 70° to 90° in the same direction; and it would go back to its original place as soon as let free.

This was a sufficient proof of its great sensibility; but to make sure whether moisture or heat caused it to move in the two preceding cases, I had recourse to the following:

EXPERIMENT III.

I first applied a ret-hot bar of iron, as close to the stem as could be contrived without burning it, which moved it uniformly from *right* to *left*.

Again, having prepared another stem, I applied the steam of hot water, issuing from the spout of a tea-kettle; which caused it to move, with great violence, several revolutions from *right* to *left*: which was a sufficient proof, that heat acted on this grass only in as much as it deprived it of its moisture.

I then proceeded to ascertain, whether the stem was any way regularly affected by the changes in the atmosphere; a point on which every thing depended. With this view I made up three hygrometers, on the following construction:

Three stalks were taken, of the same length and number of twists, and, being fixed at one end into a piece of wax, with an index (as above described) the whole was fixed at the bottom of so many strong tin boxes, about $2\frac{1}{2}$ inches deep, on the edge of which was placed a moveable broad pasteboard circle, graduated every 5°, and divided in the common way of 360°*. These three hygrometers were then placed together, and observed, for two successive days, at every hour of the day, from 7 o'clock in the morning to 8 in the evening; noticing at the same time both the barometer and thermometer, as the annexed tables will shew.

* This graduation will, I trust, appear perfectly sufficient, when it is considered, that the mere effluvia arising from perspiration moved the index 88 or 108, as above mentioned.

Table, shewing the comparative rate of going of three Hygrometers.

Days and Months.	Hours.	Thermometer.	Barometer.	HYGROMETERS. No. 1.	Difference.	No. 2.	Difference.	No. 3.	Difference.	REMARKS.
5th	8	77		15	5			10	5	Light clouds, sunshine.
	9	78		20	35			15	40	Ditto, ditto.
	10	75		15	170			25	185	Ditto, light breeze.
	11	77		185	160	215	165	210	165	Sun shines.
	12	79		345	130	380	130	375	130	Bright sunshine, light air.
	1	80		475	110	510	120	505	105	Ditto.
	2	86		585	75	630	85	610	85	Ditto.
	3	87		660	15	715	25	695	20	Ditto.
	4	82		675	5	740	5	715	5	Ditto.
	5	83	27	680	95	745	85	720	110	Squalls all about.
	6	80	27	585	73	660	45	610	60	Ditto, ditto.
	7	78	33	512	152	615		550	165	Cloudy.
	8	78	27 65	360	140			396	150	Cloudy.
6th	7	71	27	+220	20	240	25	240	15	Cloudy and windy.
	8	74	27 05	+200	75	215	65	225	75	Ditto, ditto.
	9	73	27 05	+125	110	150	105	150	150	Ditto, ditto.
	10	74	27 05	+ 15	185	45	[illegible]		[illegible]	Ditto, ditto.
	11	75	27	—170	170	— 90		—175	175	Ditto, ditto.
	12	77	27	—340	165			—350	170	Sun shining occasionally.
	1	79	27	505	100	510	75	520	[illegible]	Ditto, ditto.
	2	80	26 75	605	85	585	125	605	90	Ditto, ditto.
	3	81	27	520	70	460	105	515	80	Light clouds.
	4	81	27	590	70	565	100	595	75	Cloudy.
	5	81	27	660	5	665	10	670	10	Ditto.
	6	80	27	665	35	675	30	680	45	Ditto.
	7	79	27	630		645		635		Ditto.

N. B. In this table Zero is to be taken between the signs + and —.

It may, however, be proper to mention, that notwithstanding the great regularity which appears to prevail between the rates of going of these hygrometers, whenever the atmosphere was uncommonly moist, the exquisite sensibility of the stem required to be checked; for, as it would sometimes, during a heavy shower, revolve a whole revolution, it was not to be expected, that the three instruments would keep pace, whilst moving so briskly. A silk thread was therefore fastened at each end of the index, loaded with a thin plate of lead, hanging loose on the bottom of the box, so as to be dragged by the straw as it went round. By these means the instruments were easily regulated.

EXPERIMENT IV.

Application of heat, to determine the compass of the instrument.

Having fixed a stem, of six twists, in such a manner as to admit it, I brought a bar of heated iron as close to the stem as could be done, without setting fire to the apparatus; on which the index revolved, 2 revolutions and 105°, from *right* to *left*, when it became quiescent. That is, the heat of the iron affected it no longer in that direction, and was barely sufficient to keep the index from falling back.

The heated bar being withdrawn, the index began to recede, and became quiescent again (that is in its natural position) after having returned 290°.

But the three hygrometers, whose rate of going is given in the preceding table, had moved, meanwhile 204° towards it; and therefore this quantity is to be added to the above.

Namely 290°
+204
Rev.
494=1+134°

Whence it will appear, that since the index had moved, by the application of heat, Rev. 2+105=825°
and that, by cooling, it only recovered 1+134=494

it follows, that the stem, by being deprived of its radical moisture, lost a power =331°

EXPERIMENT V.

Application of Moisture.

As soon as the index of the same stem gave signs of proceeding regularly with the hygrometers, a hair pencil full of water, was applied, and held to the stem, when it revolved R. 6+295° from *left* to *right*, and then remained quiescent. On the pencil being withdrawn, the index began to recede, and resumed the course of the other hygrometers, after revolving 6+300°.

But, during the interval of this experiment, these had moved 135°, in the same direction with that under observation, which quantity is therefore to be subtracted.

Namely R. 6+300
135

6+165

Again, we have seen, that by the application of extreme moisture, the index had revolved, R. 6+295°
Hence, it will appear, that this process, 6+165

affected the fibres of the stem by 130

The thermometer, at the beginning of this operation, was 77°; and at the end 79°.

From the above experiments, it will appear, that, since by the application of extreme heat (procuring extreme dryness) the index had revolved from right to left, R. 2+105°
and, by the application of extreme moisture, from left to right, 6+295

it follows, that the sum of these two quantities, viz. =9+ 40
is the compass of the stem.

This result evinces, that the mean state of the atmosphere does not correspond, nor can it on any occasion, with the mean of the power of this instrument*.

A second stem having been selected, and the same process, as above related, repeated; it moved by extreme heat R. 2+290°, and, by extreme moisture, R. 8+320°; so that the compass of this fibre was R. 11+250°; which exceeded that of the former by R. 2+210; but, on examining it closer, after the operation, it was found that, although taken of the same length, it contained one twist more than the former; which accounts for its greater compass.

EXPERIMENT VI.

Application of Steam.

Three stems having been selected, and being fixed as usual, the steam of boiling water, issuing from

* The stem, which was used for this experiment, was afterwards compared, when made up, with other hygrometers; and it did not appear to have lost of its activity, by this process.

the spout of a tea-kettle, was applied to one of them; when it moved, from left to right, with violent convulsive motions, (so rapid as hardly to admit of counting them) $6\frac{1}{2}$ revolutions; the 2d, 6; and the 3d, $6\frac{3}{4}$; when they remained quiescent.

Now, we have seen above (exp. IV.) that a stem, of this length, and number of twists, revolved in that case $\overset{R.}{6}+300°$; and, in the present, nearly $\overset{R.}{6}+180$ (on a mean of three). The application of steam, therefore, if we consider the small difference of the two results, may be conceived to have affected the stem, only in as much as it moistened it.

Several other experiments were also tried, but being of the same nature as the foregoing, and the results nearly similar, they need not be particularized.