

S Y M O N S'S

MONTHLY

METEOROLOGICAL MAGAZINE.

LXXI.]

DECEMBER, 1871.

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BRITISH RAINFALL.

WE desire to bring the following letter, which appeared in the *Times* of Dec. 9th, under the notice of our readers, and shall be glad if they also will convey its purport to any persons who may be observing, but not yet communicating the results :—

“Mr. G. J. Symons writes to us on the subject of rain gauges under date 62, Camden Square, N.W., Dec. 8 :—

“The time has again come round at which it is requisite to ascertain the completeness of the corps of observers of rainfall in the British Isles, and to endeavour to obtain fresh ones in those districts in which no observations are now made, either from the death or removal of previous observers. At the Edinburgh meeting the British Association voted a small sum of money to provide rain gauges gratuitously for certain localities, but the first necessity is to ascertain exactly and completely all the places at which observations are now being made.

“In furtherance of this primary object I trust that you will (as on former occasions) allow me to ask any of your readers who may be recording the fall of rain, or intending to record it, who are not already in communication with me, but are willing to assist by forwarding copies of their observations, to at once oblige me with their names and addresses, so that duplicate gauges may not be started unnecessarily near to them.”

Moreover, we have another request to lay before our readers, viz., that they will endeavour to procure observers in any of the undermentioned localities. Surely among our numerous correspondents, some must have friends resident, or property, in some of these localities. As very heavy demands have already been made on the British Association grant, it is desirable that as far as may be the new observers purchase their own gauges ; but we hope it will be distinctly understood, that in the neighbourhood of any of the undermentioned localities, gauges will be provided gratuitously on loan, if desired.

Berkshire.—East Isley.

Cambridge.—March, Ely, (a gauge on or near the ground required.)

Cheshire.—Tarporeley, Middlewich.

Cornwall.—Lostwithiel, Saltash, Camelford, Jacobstowe.

Cumberland.—Ulpha, Ravenglass, Hesket Newmarket, Kirkoswald, Alston.

Derbyshire.—The South-western part of the County.

Devon.—Hartland, South Brent, Exmoor.

Dorset.—Beaminster, Bere Regis.

Gloucester.—Upton-on-Severn

Hampshire.—Freshwater I.W., Lyndhurst, Stockbridge, Whitchurch.

Hereford.—Bromyard.

Kent.—Romney, Wye, Strood, Sheerness, Tunbridge.

Lincoln.—Sleaford, Horncastle, Kirton, Saltfleet, Epworth,

Norfolk.—Thetford, New Buckenham, Cromer, Holt, Lynn.

Northumberland.—Along the Cheviots.

Somerset.—Minehead, Dulverton, Castle Cary, Weston-super-Mare.

Stafford.—Eccleshall, Crewe.

Suffolk.—Debenham, Halesworth, Mildenhall.

Sussex.—Ticehurst, Chiltington.

Warwick.—Kineton, Southam.

Wiltshire.—Devizes, Malmesbury.

Yorks.—Hornsea, Bridlington, Hawes, Masham, North York Moors.

WALES.—Gauges are more or less wanted throughout the Principality, excepting in Major Mathew's district around Carnarvon, the positions in which the want is greatest will readily be seen by reference to the tables in last year's *British Rainfall*.

SCOTLAND.—We have much pleasure in announcing, that through the courteous co-operation of the directors of the Highland and Dingwall and Skye Railways, a series of observations will be commenced at a large number of their stations on the 1st of January next, which will go far towards supplying information, of which we have been long in want. We are also indebted to Mr. Buchan for several new stations, but, after all, much remains to be done, and there are few parts of the country from which additional returns would not be welcome. The following list contains only a few of the more important :—

Aberdeen.—Huntly, Banchory.

Argyll.—In Cantyre, on Loch Awe, North-east of Ben Cruachan.

Banff.—Banff.

Berwick.—On Lammermuir Hills.

Caithness.—Any station inland.

Forfar.—Forfar, Glen Esk.

Inverness.—Within 10 miles on either side of Caledonian Canal, near Loch Rannoch.

Kincardine.—Stonehaven.

Linlithgow.—Linlithgow.

Peebles.—Biggar.

Ross.—Between Loch Broom & Gairloch, Ben Wyvis.

Stirling.—Kilsyth.

Sutherland.—Any station inland, except Lairg.

Wigton.—Newton Stewart, Port Patrick.

IRELAND.—Reference to the last year's volume of *British Rainfall* will show that the representation of this country is steadily becoming more complete ; we shall, however, gladly welcome any offers of additional returns, and promise our warmest co-operation.

We need hardly point out that this notice should be acted upon with extreme promptitude, or the observations cannot be commenced for the new year.

EVAPORATION.

To the Editor of the Meteorological Magazine.

SIR,—Discussion on any question is no doubt one of the best methods of arriving at the truth, and I cannot expect that the conclusions drawn in my paper on evaporation should pass unchallenged, but looking to what has taken place upon "Decrease of rainfall with elevation," I have the strongest possible objection to enter into a controversy upon so difficult a subject as evaporation ;—and must therefore ask your correspondents not to accuse me of want of courtesy if in future, I abstain from replying to their communications. With these remarks, I ask permission to say a few words upon Mr. Hudson's

letter which appeared in your last number ; for the sake of brevity, in speaking of the temperature of the dew point, the words "dew point" only are used.

Proposition No. 1 is qualified by No. 2, but if read alone it is incorrect. I should prefer it as follows :—

When air is saturated with moisture, and the water is of the same temperature as the air, neither evaporation nor condensation can take place.

I do not like the words "when air is saturated," with which the three first propositions commence, not from their incorrectness, but from the tendency they have to convey a false impression; except as it affects the dew point, it is a matter of little consequence whether the air is saturated or not; other circumstances being the same, it is the difference between the temperature of the water and that of the dew point which determines the amount both of evaporation and condensation.

In Paragraph 5, page 167, a case is supposed, which in my opinion can never exist; air under the circumstances named is *not* "capable of abstracting vapour," and therefore *cannot* "surrender its previous spoils again;" on the contrary, strange as it may appear, water of a lower temperature than the dew point, will rob the driest air of a part of the small quantity of moisture which it contains; this I have found to be the case, by placing water of a lower temperature than the dew point, in the heated air of a drying-room, when I have invariably found it to increase in weight.

It is quite true that in Table 2 of my paper, evaporation appears to take place from water when at a lower temperature than the dew point, but it will be observed that the words "calculated dew point" are generally used, and the tendency of my experiments was to throw a doubt upon the correctness of the tables used for the determination of the dew point; further experiments have convinced me that they require correction, that they generally, but not always, give the dew point too high, but some anomalies which I have noticed, and to the solution of which at present I can see no clue, lead me at times to doubt if the wet and dry bulbs can ever give more than an approximation to the moisture in the atmosphere.

The time at which evaporation commences from water, or from any other substance covered with moisture, in its relation to the dew point, is a question of great nicety, to be determined only by the most careful experiments. To me it has sometimes appeared to differ, in different currents of air, but the whole question is beset with difficulties of no ordinary kind, one of which would be to determine the temperature, not of the water, but of its surface, and at the same time to get the correct dew point; the latter at times appears very changeable, the moisture in the air, if I may be allowed the expression, is badly mixed, masses of air very differently charged with moisture, are rolling over the surface of the earth, in the same manner as the clouds above, the difference being that they are invisible.

I cannot agree with the conclusion Dr. Hudson has drawn, that water will evaporate when at a temperature several degrees below the dew point; it certainly does not do so when the air is nearly saturated; his reasonings with regard to water appear to me to apply also to any other substance covered with moisture, and the important bearings which such a state of things would have in retarding the formation of dew must not be overlooked.

I will only add that at present much of what is said both by myself and others, upon this difficult subject, must be received with some reserve, but up to the present time nothing has occurred to alter my conviction of the truth of one leading idea, namely, that if the surface temperature of water or of any other substance be colder than the dew point, condensation will take place, and on the contrary, if the surface of water, or of any other substance covered with moisture be warmer than the dew point, evaporation will ensue.

GEORGE DINES.

Cobham, Surrey, Dec. 1st. 1871.

THE WINTER AND COMING SUMMER.

To the Editor of the Meteorological Magazine.

SIR,—The following rule seems to show that the Yorkshire rainfall in November, often indicates the character of our coming winter and summer. It does not, however, appear to apply to spring seasons. The rule may be thus stated:—

When the rainfall of November has been below 2 inches at Well Head, near Halifax, in Yorkshire, (the mean fall for November there is 3 inches); the succeeding winter and summer have each had a mean temperature above the average of 100 years.

The following are *all* the instances since 1829, (when the monthly rainfall records at Halifax appear to have commenced). The rainfall amounts are taken from the table of Mr. Waterhouse, the mean temperatures from Mr. Glaisher's Greenwich tables.

Year.	Rainfall of November, at Well Head, Halifax.	Year of Winter.	Difference of Mean Temp. of Dec. to Feb. inclusive, from Greenwich average of 100 years.	Year of Summer.	Difference of Mean Temp. of June to Aug. inclusive, from Greenwich average of 100 years.
	inches.		deg.		deg.
1833	1·50	1833-4	+5·2	1834	+2·4
1845	1·85	1845-6	+5·2	1846	+4·2
1848	1·95	1848-9	+4·5	1849	+0·9
1851	0·80	1851-2	+3·2	1852	+1·5
1855	0·96	1855-6	+1·1	1856	+1·0
1856	1·27	1856-7	+0·8	1857	+3·9
1857	1·40	1857-8	+1·2	1858	+2·4
1858	1·47	1858-9	+3·6	1859	+4·2
1862	1·06	1862-3	+4·6	1863	+0·2
1867	0·62	1867-8	+1·3	1868	+4·2
1871	0·87	1871-2			

It will be seen from the foregoing table that, as the rainfall of last month, at Halifax, was only 0·87 in., the winter of 1871-72 should be

somewhat warmer than the average. I may here remark that the season most resembling the present was that of 1782, when, according to the tables of Mr. Barker, of Lyndon, September had an enormous rainfall, and *November was very dry*. Mr. Glaisher says, "it was severe in November, 1782, and during the first half of December." The latter half of December 1782, was, according to Mr. Barker, mild. The rest of the winter of 1782-3, was, on the whole mild, and the succeeding summer very hot, exactly in accordance with the foregoing rule.

During the last 57 years, or as far back as the Greenwich records go, there have only been 4 years when the November rainfall at that station was below one inch, viz, in 1851, 1858, 1868, and 1871; and in the following summers of 1852, 1859, and 1868 very great heat occurred, according to the above table, however, the coming summer may be, (as in 1863), only a little warmer than the average.

We sometimes have a cold summer after a mild winter, as in 1833, 1862, and 1866, and sometimes a hot summer after a cold winter, as in 1780, 1808, 1847, 1865, and 1870; but it appears that when a mild, or rather mild winter occurs after a dry November, we always have a warm or hot summer follow.

It is a remarkable fact, that *all* the summers of maximum heat, that is all the summers that had a mean temperature of about 4 degrees in excess of the average, were preceded by dry Novembers at Halifax. The only summers during the last 100 years, in which the mean temperature at Greenwich reached 64 deg., were 1846, 1857, 1859, and 1868, and all these dates occur in the above table.

It is also a remarkable fact, that in the only instance of 4 hot (including 3 extremely hot) summers occurring in immediate succession, (I mean the summers of 1856, 57, 58 and 59); there was a corresponding exceptional succession of dry Novembers at Well Head, Halifax.—I am &c.,

GEORGE D. BRUMHAM.

Barnsbury, Dec. 7th, 1871.

AUTUMN DROUGHT AT BRIGHTON.

To the Editor of the Meteorological Magazine.

SIR,—The drought during the past two months has been so remarkable here, that a few particulars will, I think, be interesting to your readers.

The September rainfall was above the average, owing to the heavy rains in the last few days. In October, which is a very rainy month here, the total was remarkable; ranging in various parts of the town from 1.42 in to 1.69 in., whilst the mean of 21 years is 3.83 inches, so that the *deficiency was about two-and-one-third inches*. In October of the following years the totals were very small—1850, 1.85 inches recorded at Terminus Road; 1858, 1.53 inches at Clifton Terrace; 1860, 1.76 inches at the Water Works; and in 1864 at the same place 1.75 inches, and at Cambridge Road 1.40 inches. I think, therefore, that this year's October rainfall may be regarded as the lowest since 1842. November was again dry, and I can find no

instance in which October and November successively were as dry as in the present year. The totals range from 0·58 in., to 0·85 in., the 21 years mean is 2·41 in., so that there is again a *deficiency of about one-and-three-quarters inches*. In the years 1851 and 1853, 0·91 in. was recorded at Terminus Road, and in 1862, 0·76 in. at the Water Works, therefore this November is, I think, the driest since 1842.

The following table shows the totals in various parts of the town, for the three autumn months, and also the totals in previous dry years.

Autumn Rainfall, 1871.

	Sept. in.	Oct. in.	Nov. in.	Total. in.
Water Works, Lewes Road	3·44	1·69	0·77	5·90
Do. Goldstone Bottom	3·38	1·44	0·85	5·67
55, Buckingham Place (F. E. Sawyer)	3·19	1·44	0·67	5·30
Do. 35 ft. above ground	2·89	1·20	0·44	4·53
St. James's Street (E. Rowley, Esq., F.M.S.)	3·55	1·49	0·58	5·62
14, Eaton Place (Dr. S. Barker, F.M.S.)	3·41	1·42	0·66	5·49
Mean, 21 years (1849 to 1870)	2·68	3·83	2·41	8·92
1851—Terminus Road	0·16	2·87	0·91	3·94
1858—Clifton Terrace	1·32	1·53	1·30	4·15

Thus it will be seen that the autumn total this year is more than 3 inches below the average, that it is the lowest since 1858, and with the exception of that year and 1851, is the lowest of the past 29 years.—I am, Sir, Your obedient Servant,

FREDERICK E. SAWYER, F.M.S.

55, Buckingham Place, Dec. 5, 1871.

THE EXPERIMENTAL THERMOMETERS IN THE FROST.

To the Editor of the Meteorological Magazine.

SIR,—Under the above heading I sent to you in January, 1870, a short note of the minimum temperatures recorded on the various thermometer stands on December 28th, 1869. It may possibly be of interest to supply similar details as to the extremely low temperature on the 19th ult.—Yours truly,

C. H. GRIFFITH.

Strathfield Turgiss Rectory, Winchfield, Dec. 1st, 1871.

Minimum Temperatures recorded at 9 a.m. Nov. 19th, 1871.

James	15°·3	Morris's	19°·4
Martin	16°·0	Griffith's	15°·0
Stevenson	18°·7	Kew	16°·8
Glaisher	15°·7		

[We think the variation in the two instances (see *Meteorological Magazine*, Vol. IV., p. 186,) on the whole may be considered satisfactorily accordant. The higher temperature shown by Stevenson's stand on the recent occasion, is doubtless due to its having been removed from the thermometer enclosure to the partial shelter of the Rectory, near Morris's stand. This was purposely done, to determine the influence of such shelter.—ED.]

REVIEW.

Meteorological Report for the Year 1869. Edited by the REV. R. F. WHEELER, M.A. [From the Natural History Transactions of Northumberland and Durham.] 8vo, 109 pages.

Meteorological Report for the Year 1870. Edited by the REV. R. F. WHEELER, M.A. 8vo, 43 pages. Newcastle : John Bell.

WE extremely regret to find the following notice affixed to the cover of the last mentioned work :—

“ The Rev. R. F. Wheeler finds that the demands made upon his time by other duties compel him to resign the Editorship of the Meteorological Report. He quits the work with the greatest regret, as it is one in which he took an ever-growing interest, and which brought him into pleasant communication with many friends.”

Considering the extremely complete and careful manner in which Mr. Wheeler has worked up these reports, and the development which they have received under his direction, we are not at all surprised to learn that the work has become too heavy to be carried on simultaneously with his other duties, nor that the Field Club have had considerable difficulty in finding a successor. We thank him for the information he has collected, for infusing something of his own energy into many of his correspondents, and especially for setting a good example for his successor to follow.

Having on several previous occasions drawn attention to, and described these reports, it is unnecessary for us to say more than that the two now before us are equal or superior to any of the previous ones, full of facts and figures, and very free from errors and misprints. Some indication of the benefit conferred by local publications of this kind is afforded by the preservation of the following instructive details:—

“ On the afternoon of the April 14, in the midst of a severe storm of thunder and lightning, with the wind varying constantly in different directions, a whirlwind swept over the farm of Sweethope, on the estate of Sir W. C. Trevelyan, Bart. It commenced its work of destruction on the S.W. of a small plantation and passed on to the north-east side. Every tree was uprooted and scattered in various directions. A strong stone wall, seven yards in length, next succumbed to its violence, then passing over a field it levelled seventy yards more of wall. It then came in contact with a flock of sheep whirling them up into the air killing five, and breaking the legs and tearing off the horns of several others. Sweethope Lough was next visited. Here one side of the room over the boat-house was carried away, the walls and beams below being also lifted out of their places. Close by, a stable had been built which was entirely thrown down, and a large beam of wood carried between seventy and eighty yards away. The spars and slates were found scattered about in all directions, hundreds of yards away from the spot. Pieces of slate were driven fast into the fir trees. Meeting another wood in its course it made a passage ten yards in width, uprooting hundreds of trees, snapping many in half, and breaking others at various heights from the ground. It overthrew a stack of hay about 400 yards away from this last plantation, and then ceased.

“ The appearance of the wind was that of dense white mist, and the shape triangular, with the apex downwards.

“ On the same day there was a heavy fall of hail about 3 P.M., which broke several squares of glass in the vineries and plant houses, and cracked others.”

We hope that Mr. Wheeler will still find leisure to continue his efforts towards obtaining rain returns from the higher parts of the Cheviots, and that they will be warmly seconded by the new editor.

NOVEMBER, 1871.

Div.	STATIONS. [The Roman numerals denote the division of the Annual Tables to which each station belongs.]	RAINFALL.					Days on which 40 or more fell.	TEMPERATURE.				No. of Nights below 32°	
		Total Fall.	Differ- ence from average 1860-5	Greatest Fall in 24 hours.		Max.		Min.		In shade	On grass		
				Dpth	Date.			Deg.	Date.			Deg.	Date.
I.	Camden Town .....	.60	— 1.81	.22	14	8	52.5	1	21.0	19	15	21
II.	Maidstone (Linton Park) .....	.76	— 2.43	.16	1	10	55.0	16	22.0	19	15	...
III.	Selborne (The Wakes) .....	.57	— 2.97	.23	14	5	52.0	8	16.0	19	21	23
III.	Hitchen .....	.93	— 1.21	.28	14	14	49.8	8	20.0	18	22	...
IV.	Banbury .....	.80	— 1.40	.32	14	11	50.7	8	17.0	19	24	...
V.	Bury St. Edmunds (Culford)	1.52	— .87	.54	14	9	51.0	3, 15	20.0	18	22	27	
V.	Bridport	1.29	— 1.87	.42	14	6	56.0	15	22.0	18	10	...	
"	Barnstaple	1.79	— 2.35	.43	24	11	54.0	16	27.0	12	...	...
"	Bodmin	1.87	— 3.11	.32	14	12	51.0	1	28.0	18	2	7	
VI.	Cirencester .....	.40	— 2.39	.35	14	...	...	...	...	...	...	...
"	Shiffnal (Haughton Hall) .....	.89	— .68	.20	14	15	49.0	15	20.0	19	21	...
"	Tenbury (Orleton) .....	.80	— 1.67	.23	14	12	52.8	15	20.0	13	16	23
VII.	Leicester (Wigston)	1.04	— 1.12	.43	15	8	52.0	15	20.0	18	...	...
"	Boston	1.33	— .81	.58	14	10	51.0	1	25.0	19	16	...	
"	Grimsby (Killingholme)	2.29	..	.45	27	16	50.0	1, 3*	24.0	19	11	...	
"	Derby	1.05	— .58	.68	14	13	52.0	1, 15	21.0	19	14	...	
VIII.	Manchester	1.41	— 1.35	.75	14	10	51.8	15	24.0	12	14	21	
IX.	York	1.25	— .73	.42	14	12	50.0	1	14.0	19	19	...	
"	Skipton (Arnccliffe)	2.13	— 4.32	1.17	14	10	50.0	3	15.0	16	14	...	
X.	North Shields	1.84	— .86	.29	10	18	51.0	15	26.0	19	13	15	
"	Borrowdale (Seathwaite)	6.24	— 10.43	2.78	15	10	...	...	...	...	...	...
XI.	Cardiff (Town Hall) .....	...	...	...	...	...	...	...	...	...	...	...
"	Haverfordwest	1.81	— 3.86	.80	14	13	54.0	14	24.3	17	8	10	
"	Rhayader (Cefnfaes)	1.24	— 3.34	...	...	16	51.0	...	20.0	...	...	...
"	Llandudno	3.24	+ .08	.91	21	13	55.2	14	32.9	19	...	...
XII.	Dumfries	2.31	— .91	.98	14	9	52.5	15	19.5	18	13	...	
"	Hawick (Silverbut Hall)	2.09	...	.50	29	13	...	...	...	...	...	...
XIV.	Ayr (Auchendrane House)	2.80	— 1.27	.68	14	14	59.0	20	19.0	18	12	19	
XV.	Castle Toward .....	...	...	...	...	...	...	...	...	...	...	...
XVI.	Leven (Nookton)	3.43	+ .39	1.01	20	16	52.0	14+	23.0	13+	15	24	
"	Stirling (Deanston)	3.13	— .38	.99	21	10	53.5	14	19.0	18	21	23	
"	Logierait	1.16	...	.29	21	10	...	...	...	...	...	...
XVII.	Ballater	1.22	...	.37	10	9	50.5	14	21.0	18	17	...
"	Aberdeen	2.49	...	.43	7	25	50.2	1	29.2	13	7	25
XVIII.	Inverness (Culloden)	2.35	...	.52	10	14	53.2	20	31.0	13	2	26
"	Portree	8.06	— 2.42	2.73	20	18	...	...	...	...	...	...
"	Loch Broom	2.69	...	.54	8	17	...	...	...	...	...	...
XIX.	Helmsdale	3.31	...	.46	10	22	...	...	...	...	...	...
"	Sandwick	4.04	+ .04	.49	20	24	50.0	14+	29.3	17	3	21	
XX.	Cork	3.43	...	.95	18	12	...	...	...	...	...	...
"	Waterford	4.39	+ .44	1.55	20	14	60.0	16	26.0	18	4	...	
"	Killaloe	2.00	— 2.89	.47	20	11	55.0	14	20.0	12	6	...	
XXI.	Portarlington	1.65	— 2.27	.44	21	19	54.0	3	23.0	17	10	...	
"	Monkstown	1.10	— 1.79	.19	29	14	...	...	...	...	6	...
XXII.	Galway	1.38	...	.42	13	13	57.0	1, 2	25.0	12	5	...
"	Bunninadden (Doo Castle)	2.57	...	.36	19	13	45.0	23**	21.0	18	14	...
XXIII.	Bawnboy (Owendoon) .....	...	...	...	...	...	...	...	...	...	...	...
"	Waringstown	1.74	...	.62	14	15	56.0	3	27.0	12	16	22
"	Strabane (Leckpatrick)	3.07	..	.50	20	20	...	...	...	...	...	...

* And 4, 15. ** And 28 + And 15. † And 19. § And 18. || And 11. ¶ And 7, 8.

+ Shows that the fall was above the average ; — that it was below it.

METEOROLOGICAL NOTES ON NOVEMBER.

ABBREVIATIONS.—Bar for Barometer; Ther. for Thermometer; Max. for Maximum; Min. for Minimum; T for Thunder; L for Lightning; TS for Thunderstorm; R for Rain; H for Hail, S for Snow.

ENGLAND.

LINTON PARK.—Brilliant aurora on night of 10th. Dense fog all day on 23rd. Early part of month fine and dry, the roads almost dusty; the middle frosty, but still mostly dry; the last week dull and dirty, but the whole month may be regarded as a favourable one, the frost not being severe enough to interfere with out-door work. Bar. generally high; wind mostly N. and N.W. For the two consecutive months—October and November, the past have been the driest I have on record, being 1·44 in. and 0·76 in. respectively—2·20 in. in all. The corresponding months in 1858 being 1·45 in. and 0·77 in., or 2·22 in. the two months, while the same months in 1865 were 8·14 in. and 2·74 in., or 10·88 in. the two.

SELBORNE.—The coldest November I have ever recorded. Very damp white frosts on 10 days; the aurora on the 9th extremely fine, the lower part a bright white light, passing into roseate; the following night there was also a fine aurora, but without colour; there was not on any day sufficient snow to measure.

CULFORD.—November entered with cold, north-easterly winds, accompanied by a very low temp. for the season, and which has continued throughout the month; ice strong enough to bear skaters, &c., about 11th, and in good order for storing in ice-houses, &c. Easterly winds prevailed on thirteen, and westerly on seven—ten, days; average temp. of the month, 36°.

BRIDPORT.—Fine, but cold; more or less easterly winds almost throughout the month; south-westerly gale on 14th; swallows seen on 7th, and one on 14th. Several raspberries picked in the garden in the early part of the month. Fine aurora on 10th.

BODMIN.—This month has been remarkable for its dryness and excessive cold.

SHIFNAL.—This month has quite surpassed its proverbial character for unpleasantness. Rain, sleet, and frost having interchanged throughout with fog on the 23rd and 24th, and although the depth of rain was (as is usual in this month) moderate, the frequent fall kept up constant damp. The easterly winds which set in at the close of October, continued for the first week, when they changed to westerly points, but went back again on the 24th for the rest of the month. Dahlias remained unscathed until the 11th, when frost set in with ice $\frac{1}{2}$ in. thick. The max. temp. never exceeded 49° (15th), and min. sank to 20° (19th), and to below 32° on 21 nights. A fine aurora on night of 9th, repeated in saffron tints less brilliantly on the 10th.

ORLETON.—A very dry month, with many bright days and much less cloud and fog than usual. The first ten days about the mean temp., the remainder of the month very cold, with severe frosts. Temp. of the month 4°·5 below the average and lower than in any year since 1862. Brilliant aurora on the nights of the 9th and 10th. S on the 21st.

WIGSTON.—An unusually dry month, the rainfall not half the mean of the month taken for many years. The temp. much below the mean of the month, nevertheless the weather has been agreeable.

GRIMSBY.—Aurora on the 10th; winter began on 17th with wind N.N.W. 8, S at intervals from 7 a.m. to 1.30 p.m., it melted partly as it fell, and very gradually for a week afterwards. Min. temp. 24° (19th); on 23rd the trees in places coated with ice, which fell in the form of oblong angular flakes at midday, covering the ground beneath.

DERBY.—This month has been unusually cold, the mean temp. being 4° below the average; the rainfall is generally light for November, but on this occasion is less than usual. The character of the month is fine, not having been visited with any decided fogs.

YORK.—Aurora on 8th, 9th, 10th, and 15th—very fine on the 10th. Slight fall of S on 15th; heavy fall of S with strong gale from N. on 17th; thick fog on 23rd; snowy showers, like April showers, with clear sky intervening, on the 28th.

ARNcliffe.—Small rainfall, but ther. unusually low for Nov.; early winter.

NORTH SHIELDS.—Fine aurora on 8th, 9th, and 10th; very fine mock sun from sunrise to 9 a.m. on 13th.

SEATHWAITE.—S on 9th, 10th, 21st, 22nd, and 30th. T on 11th.

W A L E S.

HAVERFORDWEST.—A cold, damp month, although the rainfall was below the average, the ther. near freezing point on 10 and below it on 8 nights; prevailing winds, N.N.W. and N.E.

CERNFAES, RHAYADER.—The month dry and cold, generally frosty, wind N.E. and S.E.; S on the hills, 11th, 17th, and 23rd.

LLANDUDNO.—On 3rd, fine but dull, at 2.30 p.m. a thick fog for half-an-hour over the sea and hills. T S and H at noon on 8th, showery after, at 11.55 p.m., most vivid L. Aurora on 10th. The coldest and wettest November known for some years; at the commencement of the month the wind for several days in the E.; in the latter part the wind prevailed from the N.E.

S C O T L A N D.

DUMFRIES.—The first half of the month fine, with frost at night; excessive R on 14th, fine with frosts to 19th; a week of coarse weather followed; the close of the month fine, with some frost, snow, and sleet, on 9th, 10th, 21st, 22nd, and 30th. On the night of the 9th a beautiful display of aurora borealis, and again on the 10th. The rainfall is 0.39 in. below the average of five years preceding.

SILVERBUT HALL.—An open month. Fine aurora on 9th and 10th; beautiful rainbow on the morning of the 21st; the bow appeared a few minutes after sunrise, and so strong was the refraction that the tints were reflected with a fulness and a beauty rarely to be seen even in a spring or summer rainbow. S, R, and H on the same day; snow-storm on the 29th and 30th, 6 inches deep.

AUCHENDRANE.—With a temp. below our general November mean, the other weather tests agree; the capacity of the air for vapour was small, and even that small capacity was saturated only on 8 of the 60 observations. The difference also between the mean temp. and the mean dew-point was greater than the Nov. mean, implying greater dryness of the air. In this month, reckoning the calms and variable winds as neutral, the polar and equatorial nearly balanced each other, but the half of the total rainfall fell in the week ending on Saturday, the 25th, when also occurred our principal equatorial gale; the polar winds, though strong elsewhere, never rose here to the strength of a gale. River low up to 14th, with a total rainfall of .46 in.; from 14th to 25th, river high, with a total rainfall of 2.34 in. and equatorial winds; from 25th to end, river again decreased, with polar winds and ice. Winter has commenced very severely.

NOOKTON.—Aurora on 10th.

DEANSTON.—The month began dry and frosty, and continued so with very little rain till the 14th, which was wet and stormy; slight snow shower on the 16th. Very wet and stormy on 19th, 20th, and 21st, with S 2 inches deep on night of 21st. The remainder of the month dry, frosty, and very little wind.

BALLATER.—This month opened with cold wind and occasional R; S on the hills on the 8th; bright aurora, meeting at zenith, on 10th; lunar halo on 23rd.

ABERDEEN.—A month of cold, bleak, dull weather.

PORTREE.—Fine weather the first six days; afterwards cold, wet, and stormy; a good deal of S on the high grounds, with sharp frosts from the 24th to the end of the month. A heavy gale from S. on 19th and 20th, which stripped the slates from many houses; nearly 3 in. of rain fell on the 20th.

LOCHBROOM.—Except the four days at the beginning and the six at the end, the whole month has been one of unusual severity. So far as storms, rain, cold, and early winter are concerned, a very severe month.

SANDWICK.—November has been a cold month, being 3.2 in. below the mean, but with the exception of three gales of from 40 to 50 miles an hour, which extended (with lulls) over eight different days—viz., 8th, 9th, 10th, 16th, 17th, 20th, 21st, and 22nd—the wind was moderate. The rain was very near the average, with very little snow. Aurora on 7 nights; rainbow on 15th and 23rd; large solar halo on 13th; large lunar halo on 23rd.

I R E L A N D.

WATERFORD.—Aurora appeared on 9th and 10th, being finer, more intense and brilliant on the latter night; greatest brightness in the W. and N., round to the N.E., bright rose in W., green towards zenith, rapid flashes and streamers at 9.30, assumed overhead the form of an inverted cup.

MONKSTOWN.—An unusually dry and cold November. Aurora on 10th, over almost the whole sky, some parts crimson, very rapid in motion. Ther. at wind-dow, 25° at 7 a.m. on 18th; vivid L and T at 5 p.m. on 27th. Very heavy H in Dublin at 9.55 a.m. on 30th.

GALWAY.—Brilliant aurora on 10th.

DOO CASTLE.—Fine month; a good many frosty nights; aurora on 10th.

WARINGSTOWN.—A very fine and seasonable month; wheat sowing nearly finished; rainfall very small; strong gale S.E. on 21st.

THE SEPTEMBER RAINS.

To the Editor of the Meteorological Magazine.

SIR,—In the last two numbers of your magazine you have alluded to the heavy rainfall of last September, and stated “that in the longest registers very few equal to it are to be found.”

It may perhaps interest some of your readers to know, that at my Uckfield observatory only 3.07 in. fell during the entire month, which was 0.30 in. only above the average of the last twenty-eight years; and that during this period *twice* the quantity has fallen on one occasion, and *nearly* twice on two other occasions—viz., September, 1852, 6.54 in.; 1856, 6.06 in.; and 1866, 6.12 in. The fall of rain during the last eight days of September, 1871, was as follows:—23rd, .82; 25th, .31; 26th, .50; 27th, .26; 29th, .40; total, 2.29 ins. At my Crowborough Beacon Observatory, the total rainfall for the same days was exactly 3 inches.—I am, &c.,

Uckfield, Nov. 17th, 1871.

C. L. PRINCE.

To the Editor of the Meteorological Magazine.

SIR,—Finding you have published in the last number of your Meteorological Magazine returns (including one from Chippenham), of the unusually heavy rainfalls from 23rd to 30th Sept, I enclose mine for the same period, thinking it may—though late in reaching you—still afford some interest, if only for comparison.—Yours truly,

West Tytherton, Chippenham, Wilts, 19th Oct., 1871.

F. B. GRITTON.

Rainfall at Tytherton, Chippenham, Wilts, from Sept. 23rd to 30th, 1871.

23rd,	24th,	25th,	26th,	27th,	28th,	29th,	30th,	Month,	8 days.
0.62	...	0.01	...	0.79	...	0.85	...	0.31	...
0.08	...	0.98	...	0.30	...	5.68	...	3.94	

To the Editor of the Meteorological Magazine.

SIR,—The rainfall here in September was 6.81, rather more than half of which (3.67) fell between the 23rd and 30th inclusive. This total has been twice exceeded in the last six years, viz: 12.50 in Sept. 1866, and 8.28 in Sept. 1869. The three falls, taken together, are remarkable for a dry month, and will disturb my September average for many years to come. The heaviest fall was 1.26 on the 29th, and 1.16, and 1.05 fell on the 3rd and 6th respectively. The rain here was not so confined to the end of the month as in many localities. I subjoin figures, as you may like to see them.—Yours, &c.,

FRANKLEN G. EVANS, M.R.C.S. F.M.S. &c.

Rainfall at Tynant Radyr, Cardiff, from Sept. 23rd to 30th, 1871.

23rd,	24th,	25th,	26th,	27th,	28th,	29th,	30th,	Month,	8 days.
0.32	...	0.00	...	0.46	...	0.78	...	0.46	...
0.03	...	1.26	...	0.36	...	6.81	...	3.67	

[More on this subject in *British Rainfall*, 1871.—Ed.]

DECREASE OF RAINFALL WITH ELEVATION.

To the Editor of the Meteorological Magazine.

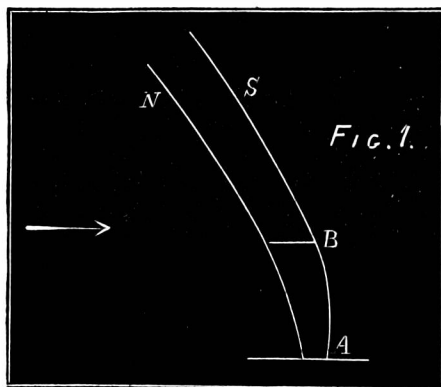
SIR,—If you do not think that sufficient space in your magazine has been already absorbed by this controversy, I beg to ask for the publication of the views contained in this letter, especially as, so far as I am aware, I am breaking new ground.

For the sake of brevity, I shall call the phenomenon in question *Altitude-Difference*.

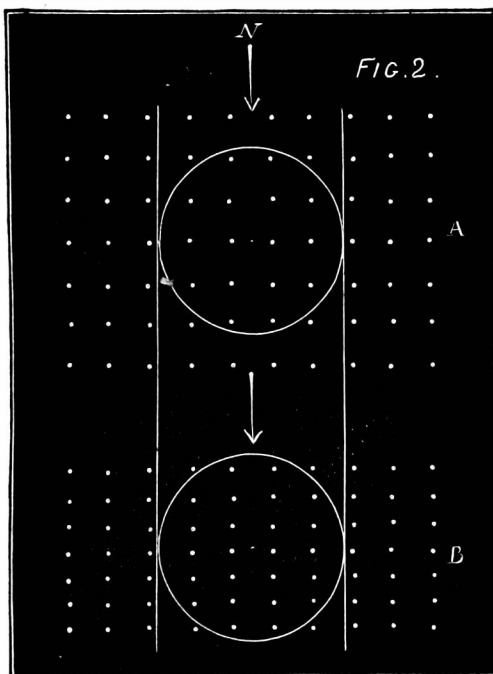
Most of your correspondents appear to think that, if they can show that rain-drops in their descent are brought nearer together, Altitude-difference must result. This, however, is not necessarily the case, as we shall see further on.

In order to explain my views, I will take first a very simple case, because the argument, if sound for that, will apply to other and more complicated circumstances.

It is a well-known fact, that currents of air at different altitudes have frequently different velocities, increasing as we ascend, when stormy winds prevail, although this is by no means always the case when the wind on the earth is moderate. Let us, however, take the case of a cloud discharging rain, having a greater velocity than the lower regions of the air, and let us assume that the wind-force continuously decreases during the descent, but that the same direction is preserved, say from the N. After the rain has fallen for a few seconds, and long before it reaches the earth, the drops, while the force of the wind remains unchanged, will be practically moving in parallel straight lines inclined at a certain angle to the horizon. As soon as they arrive at a stratum of air having a less horizontal velocity than they possess, they will experience a new resistance in a horizontal direction opposite to that of the wind. The first or southernmost layer of drops will be retarded horizontally, and will thereby lose a portion of their horizontal *vis viva* which will be imparted to the air; but, considering the relative densities of air and water, a great increase of velocity will be acquired by the air for a small decrease in that of the rain. The next layer of drops will suffer less resistance from the air thus affected, there being less difference of velocity than in the former case, and will therefore



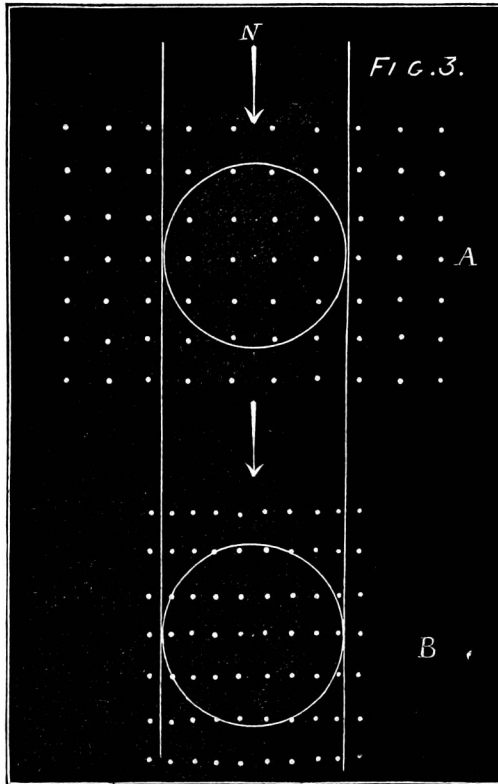
be less deflected than the first layer, and so on to the northernmost layer, which will suffer the least deflection of all ; and as, according to our hypothesis, the wind has continually less velocity as the rain descends, the shower will be more and more compressed in a direction from S. to N. as it approaches the earth, so that it will assume the form shown in Fig. 1, where the arrow gives the direction of the wind. Let us suppose there are two rain-gauges, one at A, and the other at B ; these will collect precisely the same amount of rain, (although the shower at B will last longer than it will at A) because the arrangement



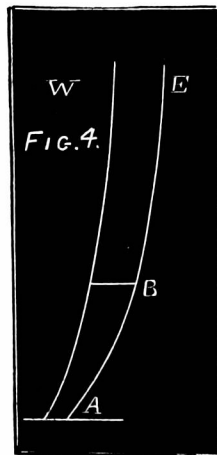
of the drops at A and B will be similar to that shown in Fig. 2, which represents cross sections of the shower at those two places, as in each case the only drops caught will be those between the two parallel lines drawn in that figure. Under these circumstances, the compression of the drops is in the direction of the cloud-wind, which I will call *longitudinal* compression, and which, as we have seen, can produce no altitude-difference.

Now, let us consider the case of a change in the *direction* of the wind between the upper and lower strata of air. Suppose the cloud-wind to be N., and that of a lower stratum to the E. of N. ; we may consider the latter as the resultant of two winds, one N. and the other E. The N. component we may neglect, because, whether it has greater or less velocity than the rain-cloud, it can only produce longitudinal compression, which, as we have seen, cannot cause altitude-difference. But the E. component is a very different affair : it will, by parity of reasoning to the former case, produce a lateral deflection of the drops, to a greater

extent on the easterly than on the westerly layers, thus giving to the shower a lateral compression in the direction E. to W., and continuing this compression to the surface of the earth ; so that, if we take cross sections of the shower at A and B, as before, we shall find the arrangement of the drops like that shown in Fig. 3 ; and as, no matter in



what direction the wind may be blowing at the surface of the earth, the shower will move from N. to S., it is evident that a rain-gauge at



A must catch more drops than an equal one at B. The shower, as viewed by an observer looking N., will assume the form shown in Fig. 4; and this is no mere hypothetical representation, but what I have frequently observed, and which led me to the above solution of the altitude-difference difficulty.

The compression of a shower, as above described, appears to be analogous to that of a very imperfectly elastic body.

My theory, then, is, that if and when rain, in its descent, passes through a stratum of air having a horizontal motion in a different *direction* from that of the rain-cloud (a circumstance, as observation has shown, of no unfrequent occurrence), altitude-difference must necessarily ensue; but this is not exclusive of any other possible mode of accounting for this phenomenon.

It is obvious that this theory will explain the cause of a deluge of rain traversing a narrow track of country, as sometimes happens during violent storms.—I am, Sir, your obedient Servant,

JOHN PARNELL.

Hadham House, Upper Clapton, Nov., 1871.

To the Editor of the Meteorological Magazine.

SIR,—It appears to me that Mr. Cator has made a serious error in one step of the proof of his theorem in this month's magazine, so that, unless I greatly mistake, the results worked out are utterly opposed to the correct state of the case. I refer to page 185, where Mr. C. says, "Next suppose the position CH to be horizontal, then the diameter of the gauge will catch a less number of drops, their direction in this case making a small angle with the vertical," and so on, down to the 14th line. Now, I submit that the *angle of the rain* has nothing to do with this effect, but that the *sole cause* of the diameters CH, CK, CN catching a *less number* of drops than CG is, that there is a *greater space between the drops* as they fall upon them than upon CG; in this case, we need not wonder that we get a *less number* of drops upon them (this will appear more evident by increasing the size of the diagram): the fact is, that Mr. Cator is comparing the results of horizontal gauges CN, CK, CH, CG receiving respectively rain of *different* density or volume, for Mr. C. has ignored the fact that, in a shower of a given density, the relative *horizontal* distance of the drops is *constantly the same, at whatever angle with the vertical the rain may fall*. Mr. C. assumes CN, CK, CH, CG to be horizontal, though the diagram does not show the horizontal relative distances of the drops to be equal throughout the four diameters. This serious error causes a mis-application of the results worked out in the three examples; thus, from figure 1, Mr. C. finds "that when rain falls at an angle of 30° with the vertical, a horizontal gauge loses one-seventh of the rainfall." The fact actually deduced is, that a gauge will catch one-seventh more rainfall, if we tilt it up from a horizontal position to one at right angles to a shower falling at an angle of 30° with the vertical. So from figure 2 the deduction should be stated: when rain falls at an angle of 45°, a

gauge will catch five-twelfths more rainfall if we tilt it up from a horizontal position to one at right angles with the rain. From figure 3 : when rain falls at 60° with the vertical, a gauge will catch twice as much rain if we tilt it up from a horizontal position to one at right angles with the rain. The deductions are comparisons of *horizontal* and *inclined* gauges, a very different thing from the comparison of horizontal gauges receiving rain at *different angles with the vertical*.

Mr. Cator's diagram clearly brings out, as all mathematical figures must do, the truth of the fact, that *the angle* of rainfall does *not* affect the *quantity* received by a given *horizontal* surface.

With respect to the decrease of rainfall with elevation, I have a strong persuasion that the *velocity of the wind* (the cause of angle of rain with the vertical) is also the *cause* of loss of rain, as shown by a horizontal gauge at an elevation : (1) the wind rebounds from the interior of the funnel, (2) eddies are produced around the gauge, (3) the out-splash of rain is great, from the violence and perpendicular direction with which it is driven upon a small area of the interior part of the funnel. Experiments have shown that gauges inclined at 45° do *not* show the loss of rain at an elevation, and I conceive that the wind and rain in this case are driven nearly perpendicularly down the mouth of the gauge, meeting no opposed part of the funnel, so that the rain reaches its destination, undiminished in quantity, neither blown away nor out-splashed.—Yours truly,

G. WARREN.

Merton Villa, Cambridge, Nov. 20, 1871.

SIR,—If you will allow a little practical knowledge a place in this discussion, it may possibly aid in solving the problem, which as I understand it is—*Why does a gauge perched upon a pole collect less rain than a gauge on the ground?—and why does a gauge placed on a hill of equal height with the pole collect more than the gauge at the bottom of the pole?* To begin, I assume that the pole and the hill are in different places, and that the results were obtained from different rain-clouds. My experience was gained in the mountains of Western India, where the rainfall is magnificent, and where I indulged my fancy by being constantly out in it. From an elevation of 4000 ft. I have seen storms and showers falling below me, while around and overhead it was quite clear. I have descended into the clouds, and met first mist, then drizzle, and then rain. From the top of one mountain, I have seen the crest of another, at a distance of 20 miles or thereabouts, the intervening country being hidden with clouds ; on riding into them I have found the same process, with heavy rain on the level ; on the opposite ascent I have gradually got out of the rain, and found sunshine on the hill-top. From the level plains I have seen the mountain-tops thick with clouds ; I have sometimes met the rain heavy on the ascent, and at other times heavy on the summit. From the tops of the mountains I have seen the rain-cloud rising from the distant sea, spreading over the shore, enveloping the

hills, and falling in a regular down-pour—no drops, but thick streams. I gathered from these facts, and from many others of a like nature, that rain-clouds vary in thickness from about a hundred yards to more than a mile, that the weight or size of the rain-drops increase as they reach the point of attraction—this point is the earth, and may be the mountain-top or the level plain ; as the latter does not fall in with so much moisture as the former, its chances of attraction are fewer, and the water “rests on the hills,” so that the hill gauge shows a greater fall than the gauge in the plain. I see it mentioned in your correspondence that a gauge at 100 ft. of elevation loses 40 or 50 per cent. of rain ; such instances are by no means unlikely ; I have seen rain falling from clouds not a hundred yards in thickness, so that 100 ft. of elevation above the line of attraction would get up into the drizzle before the drops are formed ; this drizzle and the haze above it move faster than the rain-drops, so that a gauge running up into the cloud-moisture could not receive so much water as that placed on the attracting line, simply because the water is not formed. Of all the able and interesting correspondents in your November number, Mr. Franklen G. Evans is the only one who approaches the truth ; he has mountains near him, and it is only in such districts that opportunities are given of looking into cloud phenomena ; some seem to think that a cloud discharges its contents in actual rain-drops ; if it did, there would be no moisture left to go on with, but an All-Wise Creator has arranged otherwise, and while some of the vapour is accumulating into rain-drops for us, the rest is passing on to bless the dry earth beneath. It will be obvious to you that water-spouts and thunderstorms are exceptions to the system I describe. In India there are seldom two layers or more of clouds—in England, as far as I have been able to ascertain, it never rains without two layers.

I am, your obedient servant, H. P. MALET.
Nettlebed, 20th November, 1871.

To the Editor of the Meteorological Magazine.

SIR,—As the discussion is to go on, I must beg for a few words, chiefly of explanation. I doubt whether Mr. Evans is correct in saying that the fall on mountain *tops* is greater than in valleys. There is generally an increase of 3 per cent. in each 100 ft. of elevation above the sea level. This is probably owing to the absorption of much of the rain by the drier strata of air below, as well as the greater condensation caused by the immediate proximity of the mountain masses. But when a gauge is placed on the very top of a hill, or in any very exposed position upon it, this increase is much lessened and often turned into a decrease. Hence we find the fall on the summit of Scawfell scarcely half that at the Styne ; or, to refer to my own experiments, the fall on the top of Ling Hill, in the months Oct., Nov., and Dec., nine-tenths of that in the level light-house garden, 100 ft. lower, and that in the experimental gauge field 3 in. less in

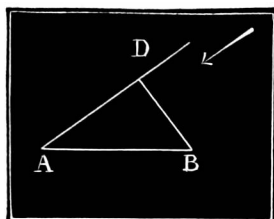
the year than that in my garden at Hawsker. That the cause of this decrease, whether the gauge be on a hill-top or a pole, is the greater obliquity of the rain at the higher station I have not the smallest doubt, but it was no part of my "original theory" to explain the precise mode in which obliquity produced this effect. About this there are different opinions, and I am not sure that at present it is possible either to explain the mode, or to prove (any more than to disprove) what nevertheless I believe to be a solid fact, that the *decrease with elevation is produced by greater obliquity of rain consequent on greater exposure*. As to the mode, I am inclined, as may be seen from my letter in your October number, to agree on the whole with Mr. Crallan. A drop of rain, however, is not simply a projectile, having a certain initial velocity, but a projectile acted on during the whole of its course by an accelerating force (*i. e.*, wind), gradually diminishing in intensity, and very rapidly diminishing as it nears the ground. Though perhaps this may only affect the shape of the curve which it describes, and not the questions at issue, if the wind is a horizontal force, which it is not always.

When I speak of drops *diverging*, I mean that the distance of their paths from one another, measured along lines perpendicular to them, increases. Surely this is the obvious sense of the words, and if this is incompatible with *preserving the same horizontal distance*, and, as Mr. Du Port says, "refutes" it, it is consoling to find that this self-refuting proposition is the same which he and Dr. Burder have been maintaining all this time as the law solely and exclusively followed by all rain-drops.

I am quite ready to admit, and in fact I so understood Mr. Crallan from the first, that during the continuance of a uniform fall of rain the height from which the drops fall should (if his theory be true) be of no importance. It is when the shower begins or ends, *or when the thickness of cloud is increased or diminished*, that it should make a difference. So far from this being an "exception with which we have no concern," it may prove to be very important indeed. Any one who has been much among mountains knows how incessantly the clouds change, lowering and lifting, parting and then closing again; and no doubt every change in the amount of rain received in a given time is accompanied by some change in the thickness of the clouds. Who has not on a rainy day observed partial gleams over and over again, followed by denser clouds, and very likely in every case the thickness of the discharging rain-cloud was altered by thousands of feet. It may be difficult to find a numerical expression for the continuity or non-continuity of rainfall, but I should not wonder if the fact which sorely puzzled me may thus find an explanation—*viz.*, that decrease with elevation is great in showery and light rains, and least, sometimes *nil*, in heavy and continuous downpours. I will try to work out some figures on the subject.

Mr. Du Port has not, I presume, observed my definition of "presenting a smaller area of aperture," or he would not have again quoted

my words in some sense of his own. Perhaps the following may be still simpler :—



If AB be the mouth of a gauge (for simplicity we neglect the width), and DAB the angle at which rain meets it, BD , the perpendicular upon AD , is a measure of the aperture which AB presents to rain falling in a direction parallel to DA , since any drops which pass without DB must pass also without AB . If rain falls vertically, DAB is a right angle, and BD coincides with AB , but if rain falls at an angle with the vertical, BD must be less than AB —that is the aperture presented by AB is less when rain falls obliquely.

I am, Sir, your obedient Servant,

FENWICK W. STOW.

Harpden, St. Albans, Nov. 22, 1871.

P.S.—I have examined my register from April, 1870, to the end of the year, and have taken out all instances in which I could approximate to the duration of each fall, dividing them into two classes, with the following result :—

<i>Falls of short duration.</i>						<i>Falls of long duration.</i>						
No. of falls.	At 1 ft.	At 10 ft.	Per-centage of fall at 1 ft	Est ^d force of wind 0—12	Duration of each fall.	No. of falls.	At 1 ft.	At 10 ft.	Per-centage of fall at 1 ft	Est ^d force of wind 0—12	Duration of each fall.	
	in.	in.			hours.		in.	in.			hours.	
20	0.060	0.055	92	3	0.5	1	0.030	0.050	167	4	6 (?)	
00	0.090	0.080	89	7	0.5	1	0.030	0.030	100	0	4	
20	0.070	0.050	71	4	0.5	2	1.990	1.950	98	1	4	
10	0.070	0.065	93	3	1.0	2	0.128	0.120	94	2	5	
10	0.050	0.050	100	1	0.5 (?)	2	0.355	0.325	91	3	6	
30	0.212	0.190	90	5	1.0	1	0.470	0.430	91	3	5	
10	0.230	0.212	92	6	0.5	1	0.140	0.100	71	4	4.5	
10	0.105	0.090	86	6	1.0	2	0.140	0.130	93	3	12	
10	0.090	0.075	83	2	2.0	2	1.250	1.200	96	5	9	
10	0.080	0.070	87	4	2.0	3	2.500	2.330	93	7	17	
10	0.090	0.080	89	5	1.0	3	0.710	0.685	96	9	3	
10	0.035	0.025	71	7	2.0 (?)	1	0.830	0.800	96	8	5 (?)	
20	0.070	0.055	79	2	0.5	2	0.342	0.310	91	5	3	
60	0.360	0.300	83	4	1.0	1	0.380	0.365	96	5	7	
						1	0.615	0.568	92	4	16	
						1	0.220	0.210	95	1	6	
						1	0.440	0.430	98	4	9	
Sums	23	1.612	1.397		59	14.0	27	10.570	10.033		68	121.5
Means		0.070	0.061	86.6	4.2	0.6		0.391	0.371	94.9	4.0	4.5

The result is certainly remarkable, and the more so that the force of the wind was so nearly equal in both cases. Is it possible that the drops shelter one another, and so the tail of a shower converges towards the middle of it?

F. W. S.

To the Editor of the Meteorological Magazine.

SIR,—I must apologize for sending you another letter on this subject, of which you must be heartily sick.

So far from there being any real discrepancy between Mr. Stow's figures on page 71, and those of Mr. Cator in your last number, the latter are a complete verification of the former; and Mr. Cator might have avoided the trouble of his formula and calculations, deducing his results from Mr. Stow's in the following simple manner:—

$$\begin{array}{rcl} \frac{13}{100-13} \times 100 = 14.94\dots & \text{for an angle of } 30^\circ. \\ \frac{30}{100-30} \times 100 = 42.85\dots & \text{,,} & 45^\circ. \\ \frac{50}{100-50} \times 100 = 100 & \text{,,} & 60^\circ. \\ \frac{100}{100-100} \times 100 = \infty & \text{,,} & 90^\circ. \end{array}$$

The trifling difference in the results in the two first per-centages merely arises from Mr. Cator's approximations for the trigonometrical ratios being rather closer than Mr. Stow's: but this of course is immaterial.

It seems almost needless to point out that the two sets of figures have reference to two different things: Mr. Stow's gave us a comparison of the deficiency caused by obliquity, with what he supposed would be collected if the rain always fell vertically; Mr. Cator's on the other hand give a comparison of the amount lost with that actually collected. In other words, referring to the diagrams on page 186, while Mr. Stow was comparing FN with FC, Mr. Cator compares FN with NC.

Now with regard to horizontal, vertical, and inclined gauges, we have three laws, viz:—

- (1) The ratio of the amount of rain caught by a horizontal gauge varies as the cosine of the angle which the rain makes with the vertical.
- (2) The ratio of the amount caught by a vertical gauge varies as the cosine of the angle which the rain makes with the horizon.
- (3) The ratio of the amount caught by a gauge inclined at right angles to the showers varies as the cosecant of the angle which the rain makes with the horizon.

The first of these was stated by Mr. Stow on p. 71, and has been abundantly verified by Mr. Cator; the second is the converse of it; the third I endeavoured to establish in the October magazine, and anyone can verify it for himself.

There can be little doubt I think, of the *general* truth of these laws; and none whatever, if we may do as Mr. Cator suggests, and "treat the angle made by the direction of the rain with the surface of the gauge, as the only element on which the differences of the amounts caught depend," ignoring minor considerations, about which opinions differ.

But while it may be useful and interesting to know them, these results have not in the least helped us to a solution of the difficulty. No one who thinks much about it would deny the truth of Mr. Stow's law, as showing to what extent a horizontal gauge presents a smaller aperture to oblique than to vertical rain: but this is a very different thing from admitting that if the same amount of rain fell, first vertically, and then obliquely, the amount caught by such a gauge would be different.

It appears to me that the mathematical part of the question has been exhausted. What we want to know is whether the unquestionably smaller aperture presented by a horizontal gauge to oblique, than to vertical rain, is, or is not, counterbalanced by some modified condition of the rain itself; and this question no mathematical consideration as to the extent of the decrease in aperture can in the slightest degree help us to answer. One side interprets the results to prove that in windy weather horizontal gauges catch too little rain, and the other to prove that inclined and vertical ones catch too much. This being the case, we can only adopt the suggestion of Mr. Stow at the end of his last letter.

I do not quite understand the second paragraph of that letter. I understood that Mr. Stow considered horizontal gauges in error at elevations above the ground, and I took exception to the conclusions drawn by him from the use of vertical and inclined gauges: but I never supposed anything so absurd as that he wanted other gauges inclined.

I think he is rather unnecessarily severe about the suggestion in the October Magazine, and with due deference to his unquestionably better judgment and experience, I still think, that although we cannot attempt so to *settle* the matter, it would be interesting to know the general opinion.—I am, Sir, Your obedient Servant,

REGINALD BUSHELL.

Hinderton, Neston, Cheshire, Nov. 30th, 1871.

To the Editor of the Meteorological Magazine.

SIR,—In the interesting discussion of this question, I believe that what may be called the *forces of precipitation* have been shown to be at their maximum at the earth's surface. That is to say, that (as shown by Mr. Evans and Dr. Hudson in your last issue) the aggregation of rain-drops due to electrical changes, and their condensation in falling through a relatively warmer stratum of air charged with moisture, prove rainfall to be a cumulative process. How far then is this result modified by other forces? The force of the wind is observed to be *distributive*, as when, (1) in the case of a shower, the rainfall from a cloud of given area or capacity is distributed over a more lengthened area of land, or when, (2) in more continuous rain, the *abrading force* of the wind tears off from each falling rain-drop

minute particles of vapour, and thus lessens precipitation. All observers will have noted this buoyant action of the wind, and how the angle of rainfall, varying with the force of the wind acting unequally on the heavy and light rain-drops, shows intersecting lines. Naturally therefore, "they are not surprised" if the rainfall is found to be greatest at the point where (as a rule) precipitation is least interfered with, viz : at the earth's surface.

Of course, I do not mean to say that the distributive action of the wind is uniformly as above stated ; I have seen the wind tear up a column of rainfall, and then dash it in a denser sheet of water to the ground, and I have seen the finer particles of rain cast upwards by the wind so as to wet the inside of my umbrella ; but at present I speak only of the wind's ordinary action, to arrive at a rule of observation for general application.—Yours faithfully,

HUGH INGRAM, M.A.

Steving, 7th Dec., 1871.

To the Editor of the Meteorological Magazine.

SIR,—Mr. Cator's diagram in your last number (p. 184), is so excellently devised to illustrate the point in dispute, and, to my mind, is so convincing of the truth of my own view, that I am much disappointed at finding that Mr. Cator himself holds a different view. For I cannot take any comfort from his admission that both Mr. Stow and myself "are for the most part right." My contention is that both Mr. Stow and Mr. Cator are radically, absolutely, and fundamentally wrong. I have the greatest respect for both these gentlemen, and gladly acknowledge their eminent services to meteorology, but on the point now at issue I yield not one inch of my original position.

Mr. Cator's letter divides itself into two parts. In the first part (to paragraph 5 inclusive) he proves more clearly than I have ever done (not having had the advantage of a diagram) that the amount of rain received by a horizontal surface is not affected by the inclination at which the rain falls. In the second part he endeavours to show that the amount of rain received by a horizontal surface is affected by the inclination at which the rain falls. It seems to me that one of these conclusions must be erroneous ; and I think it is not very difficult to detect the fallacy by which the latter of them is vitiated.

Mr. Cator argues justly enough from his diagram (which I beg my readers to refer to throughout the reading of these remarks), that in the case of driving rain, a smaller gauge tilted to meet the rain will catch the same amount as a larger gauge placed horizontally, and more than itself placed horizontally. "Suppose a gauge," says Mr. Cator, "the diameter of whose receiving surface is in the position C G (diagram, p. 184), and let it be moved so that its diameter will occupy successively the positions shown by the lines C H, C K, C I, C M, C N ; then it is plain that at each successive position it will catch less and less rain the nearer its receiving surface is to the horizontal ;

or, in other words, the smaller the angle the direction of the rain-drops makes with the receiving surface of the gauge."

Up to this point we are in perfect accord. But Mr. Cator further contends that to alter successively the position of the gauge with reference to the rain, will be the same thing in its effect as to alter successively the inclination of the rain with reference to the gauge. Accordingly, he directs us to vary the position of the diagram so as to make each transverse line in turn a horizontal line; and thus, if we have not all our wits about us, it is proved, before we are aware, that "when rain falls vertically, a horizontal rain-gauge catches most, and the greater the angle of deflection from the vertical, the less amount of rain such a gauge will catch. And this accounts for a gauge at a height from the ground catching less than one on the ground (except in the case of a calm), the amount caught decreasing with the height; because the higher from the ground the stronger the wind, and, consequently, the more the direction of the rain is deflected from the vertical."

It is difficult to imagine a line of argument more plausible and yet fallacious. The fallacy lies in turning the diagram about, not seeing that in so turning it we alter its meaning. Paradoxical as it may at first sight seem, the meaning of such a diagram as that to which I am referring is contingent upon the position in which it is held. A little reflection will show that this is so. If the diagram is held in its natural position, so that the line C N is horizontal (I am still referring to the diagram on p. 184), then the oblique lines represent rain of a certain degree of intrinsic density—namely, of such a degree of intrinsic density as to correspond to the vertical lines let fall from the line A B. But if the diagram is held so that the line C G is horizontal, then the lines representing the rain represent a denser rain than in the former case, as would be plainly seen if a rectangular slip were cut out of the diagram in the direction C G (*i.e.*, a slip of which C G should be one of the longer sides), and the same were applied to A B, so as to compare vertical with vertical. It would then appear that the same number of vertically falling drops which are represented between A and B are also represented between C and G, and the latter being the shorter line, it follows that the rain in the latter case is denser; the direction being in each case vertical, and the two kinds of rain being therefore strictly comparable.

Or, to put the argument in a more strictly logical form, the rain represented as falling vertically from the line A B is clearly of the same intrinsic density with the rain represented as falling obliquely from the same line, for it is the same rain, drop for drop. But the rain represented as falling vertically upon C G (the diagram being turned), is shown by the experiment just described to be intrinsically denser than the rain represented as falling vertically from A B. Therefore the rain represented as falling vertically upon C G (the diagram being turned) is intrinsically denser than the rain which the same lines represent as falling upon C G (the diagram being erect);

and therefore the meaning of the rain-lines *quoad* intrinsic density, does vary with the position in which the diagram is held.

Hence it follows that the reason why, in turning the diagram about so as to bring the lines C G, &c., to C N successively horizontal, a smaller and smaller quantity of rain falls within the length of the line, is not that the inclination of the rain is by these movements successively increased, although such increase is a fact. The real reason is that, in turning the diagram, the lines representing the rain come to represent successively a less and less dense kind of rain—a rain in which the approximation of the drops is less and less due to intrinsic density and more and more due to slope.

For it cannot be too strongly insisted upon or too constantly remembered in this discussion, that there are two distinct ways in which the approximation of rain-drops may vary. First, there may be more of them in a given horizontal space. Secondly, they may be driven by the wind in an oblique direction. In the first case the rain is intrinsically denser; more falls on the earth, and more falls in a horizontal gauge. In the second case, the approximation of the drops applies only to a measurement across their path. Their horizontal distances are unaffected, and the quantity received by the earth or by a horizontal gauge is neither increased nor diminished. In the first case, the multiplication of the drops is real; in the second case it is fictitious. I believe that it is through the overlooking of this distinction that most of the confusion has arisen. The density of a slanting rain is a fictitious density, but a tilted gauge records it as if it were real; and he who forgets that it is fictitious and for the moment regards it as real, will easily fall into the error of supposing that the horizontal gauge, because it catches less than the tilted one, catches therefore less than it ought; the truth being, not that the horizontal gauge catches too little, but that the tilted gauge catches too much.

GEORGE F. BURDER, M.D.

Clifton, 9th December, 1871.

AURORÆ OF 9TH AND 10TH NOVEMBER.

To the Editor of the Meteorological Magazine.

SIR,—On the evening of Thursday, the 9th inst., a rather fine display of aurora was seen here; on the following evening, the 10th, just before sunset, a very dark cloud suddenly appeared in the N.W., and spread rapidly over nearly the whole heavens. The setting sun, shining from under the cloud, cast a lurid glare over the landscape, resembling that of a solar eclipse when the sun is three parts or more obscured. A beautiful rainbow in the N.E.; cloudy more or less, with rain, till 9 p.m., when a very fine aurora was visible. Unfortunately, I did not witness it myself. The friend who described it to me said there was a perfect arch, like a rainbow, from N.E. to S.W., with beautiful streamers and coruscations. It would seem to have been almost as fine as that of Oct. 24th last year—Yours very truly,

JOHN THRUSTANS.

Wolverhampton, Nov. 11th, 1871.