

VII. *On the Meteorology of the Lake District of Cumberland and Westmoreland ; including the results of Experiments on the fall of Rain at various heights above the Earth's surface, up to 3166 feet above the mean sea level.*

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*Communicated by* Lieut.-Col. SABINE, *For. Sec. R.S.*

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*Introduction.*

NEARLY four years have now been devoted to the investigation of the fall of rain in the lake districts of Cumberland and Westmoreland ; and two complete years have elapsed since the experiments were commenced, with a view to ascertain the amount of rain deposited at great elevations above the sea, extending to the tops of our highest English mountains.

As the investigations proceeded, some remarkable results were elicited, which coming to the knowledge of the Royal Society early in last year (1847), the Council kindly expressed a wish to contribute, from the Donation Fund, the sum of twenty pounds towards the current expenses attending the inquiry. The donation was accompanied by a request, that as early as convenient after the close of the then current year, I would transmit to the Royal Society a *resumé* of all that I had done in this department of meteorology.

This *resumé* I have endeavoured to communicate to the Society in the annexed paper.

*Whitehaven, March 1848.*

J. F. MILLER.

TABLE I.

Fall of Rain in the Lake District of Cumberland, &c., for Six Months, commencing the 1st day of July, and ending the 31st day of December 1844.

1844.	Whitehaven.	Keswick.	Emberdale Lake, Bowness.	Stonywath, two miles west of the lake.	Loweswater Lake.	South end of Crummock Lake.	Gatesgarth.	Westmoreland.		Wastdale Head.
								Troutbeck near Kendal.	Grasmere.	
July.....	4·183	3·052	5·549	4·151	3·425	4·59	5·70	4·178	4·874	6·36
August .....	1·999	5·727	4·863	4·164	5·564	7·55	9·08	4·623	6·856	10·74
September ...	5·809	4·780	6·327	5·417	6·185	6·33	7·92	5·724	5·381	9·23
October .....	4·335	5·272	6·240	4·493	7·121	8·22	10·78	6·142	8·644	9·45
November ...	1·926	2·842	3·700	2·151	3·048	3·69	5·49	3·987	6·397	5·26
December ...	·309	·108	·790	·170	·307	·33	·47	1·022	845	·47
Total .....	18·561	21·781	27·469	20·546	25·650	30·71	39·44	25·676	32·997	41·51
Wet days.....	79	84	.....	.....	75	83	93	82	77	71

TABLE III.

Wet days in 1845.

1845.	Whitehaven.	The Floss.	Cocker-mouth.	Keswick.	Loweswater.	Crummock Lake.	Gatesgarth.	Wastdale Head.	Grasmere.	Langdale.	Troutbeck.	Seathwaite.
January .....	21	16	19	21	21	21	21	20	22	...	18	22
February.....	10	5	6	9	8	8	11	9	9	...	4	11
March.....	14	11	14	14	14	12	15	13	15	...	12	15
April .....	13	10	11	12	12	11	12	12	12	...	12	11
May .....	14	14	16	15	15	17	16	14	12	...	12	15
June .....	16	15	18	17	15	16	17	16	16	18	17	18
July.....	13	15	17	11	15	15	16	16	16	15	17	15
August .....	17	20	21	20	18	21	19	21	15	20	16	22
September ...	15	12	17	13	13	16	16	17	14	17	14	15
October .....	20	20	26	21	19	23	23	26	21	22	19	21
November ...	17	15	21	19	20	18	19	21	19	19	17	20
December ...	23	22	26	22	25	24	25	26	25	26	22	26
Days .....	193	175	212	195	195	202	210	211	196	137	180	211

TABLE II.

Synopsis of the Fall of Rain in the Lake Districts, &amp;c. of Cumberland and Westmoreland, in the year 1845.

1845.	Whitehaven.		The Plosh, 2½ miles south of Whitehaven.	Cockermouth.	Keswick.	Ennerdale Lake.	Loweswater Lake.	Crummock Lake.	Gatesgarth.	Wastdale Head.	Westmoreland.			Prevailing winds.	
	6 feet above the ground.	St. James's Church Steeple, 78 feet above the street.									Troutbeck, 9 miles N.W. of Kendal.	Grasmere.	Langdale Head.	At the coast.	At Crummock Lake.
January ...	4.541	in. 2.767	in. 4.88	in. 3.195	in. 6.426	in. 7.560	in. 7.100	in. 9.53	in. 13.78	in. 11.00	in. 7.031	in. 15.023	in. 16.81	S.W.	S.W.
February...	2.830	2.025	2.76	1.045	1.004	2.160	1.897	1.70	2.61	3.40	1.986	2.232	3.48	S.	S. var.
March.....	3.735	2.850	4.24	3.895	3.978	6.715	5.814	7.06	9.07	10.37	7.001	10.256	13.21	N.E. & S.E.	E.
April .....	2.587	1.770	2.67	2.330	4.886	5.500	4.859	7.31	10.60	7.40	5.595	6.133	10.57	N.E.	E.
May .....	1.480	.995	1.74	1.970	2.270	3.200	2.629	3.62	4.90	4.13	2.205	2.289	4.57	N.E. & E.	E.
June .....	4.099	3.172	3.86	3.090	4.032	5.550	4.954	5.97	8.02	6.15	5.206	5.010	8.25	S.W.	N.W.
July .....	2.900	1.980	3.52	2.600	4.112	5.050	5.274	6.39	8.72	5.42	4.366	6.191	8.65	S.W. var.	S.W.
August ...	6.995	5.100	7.22	8.720	8.806	10.005	8.858	11.17	15.75	12.31	5.934	10.185	15.61	N.W. var.	N.E. var.
September	3.653	2.405	4.11	3.825	5.004	5.480	4.576	6.54	8.49	7.53	4.751	6.538	9.77	S.W. & N.W.	S.W.
October ...	6.744	4.853	7.35	6.595	5.948	8.745	7.446	8.20	10.88	12.35	8.130	11.785	15.17	N.W.	N.W.
November	4.022	2.350	4.40	3.095	7.140	6.740	6.966	8.50	13.48	12.31	8.545	21.732	20.84	S.W.	N.W. & S.W.
December	5.621	3.222	6.25	6.570	8.596	10.175	9.169	11.49	17.83	16.18	15.555	23.614	24.94	N.W.	N.W.
Inches.....	49.207	33.489	53.00	46.930	62.202	76.880	69.542	87.48	124.13	108.55	76.305	121.008	151.87	S.W. var.	S.W. var.

The greater portion of the Tables for 1845, and the last six months of 1844, have appeared in the Edinburgh Philosophical Journal, but are added here for the sake of completeness.



TABLE V.  
Wet days in 1846.

1846.	Whitehaven.	The Fosh.	Cocker- mouth.	Keswick.	Loweswater.	Crummock Lake.	Wastdale Head.	Eskdale.	Grasmere.	Troutbeck.	Langdale Head.	Seathwaite.
January .....	22	25	26	21	20	21	28	...	26	23	28	25
February .....	15	14	16	13	13	15	18	...	15	16	16	15
March .....	18	19	23	23	18	21	25	...	21	20	21	23
April .....	17	21	24	22	16	22	23	19	21	20	22	21
May .....	12	13	15	13	14	12	14	15	12	13	13	14
June .....	9	10	12	10	11	11	11	9	9	9	9	11
July .....	24	24	28	27	22	23	27	27	21	22	23	25
August .....	13	13	18	17	18	18	22	19	14	17	15	16
September ...	12	13	13	11	11	14	11	11	10	9	11	12
October .....	23	23	23	24	24	25	23	23	23	20	23	24
November ...	18	17	19	18	17	17	17	17	16	18	16	17
December ...	17	16	17	14	14	17	15	15	14	7	16	16
Days .....	200	208	234	213	198	216	234	155	202	194	213	219

TABLE VI.

Temperature at Seathwaite, taken by Self-registering Thermometers made by  
WATKINS and HILL.

1846.	Maximum.	Minimum.	Mean.	Mean at 9 A.M.	On Grass.	
					Radiation.	
					Maximum.	Mean.
March .....	48°	21°	38·84	37·39	18°	°
April .....	60	30	43·68	42·78	12	4·61
May .....	65	41·5	52·47	52·54	18	8·71
June .....	84	44	64·83	63·87	23	11·80
July .....	79	50·5	59·41	58·22	12·5	
August .....	78	47	62·03	60·58	20	
September ...	76	40	58·20	56·16	21	12·00
October .....	61	30	47·91	47·50	17·5	
November ...	54	26	43·68	43·21		
December ...	47	14·5	32·13	32·05		
	84	14·5	50·318	49·43		
	At Whitehaven ...		52·295			
	Difference .....		1·977			

TABLE VII.  
Synopsis of the Fall of Rain in the Lake Districts of Cumberland and Westmoreland in the year 1847.

No.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.	XIX.	XX.	Prevailing winds at Seathwaite.
1847.	Whitehaven.			The Flish, three miles south of Whitehaven.	Cockermouth.	Bassenthwaite Halls, base of Skiddaw, 210 feet above the sea.	Keswick, 258 feet above the sea.	Vale of Gillerthwaite, Bunnerdale, 286 feet above the sea.	Loweswater Lake, 336 feet above the sea.	Foot of Crummock Lake, 283 feet above the sea.	Gatesgarth, 326 feet above the sea.	Eskdale.		Wastdale Head, 166 feet above the sea.	Westmoreland.			Borrowdale.			
	High Street, 90 feet above the sea.	Round Close, 480 feet above the sea.	* St. James's Church Steeple, 78 feet above the street.									Foot.	Head.		The How, Troutbeck.	Grasmere, 180 feet above the sea.	Langdale Head, 250 feet above the sea.	In Garden, 6 inches above the ground.	In Field, 18 inches above the ground.	Seathwaite Valley.	
Jan.	1·873	1·528	1·365	2·09	1·49	2·31	3·082	3·50	3·135	3·75	4·34	3·66	3·84	3·99	4·235	4·957	4·54	6·29	6·16	5·67	S.W.
Feb.	1·827	1·406	1·370	2·01	1·62	1·73	2·074	4·91	3·400	3·20	5·07	2·89	3·96	6·40	4·789	6·066	8·07	8·27	8·03	5·40	N.W.
Mar.	1·370	1·191	1·098	1·23	·53	1·10	1·270	2·54	1·456	2·19	2·65	1·16	1·78	1·91	2·040	3·091	2·63	2·53	2·65	2·35	N.E. & S.W.
April	2·560	2·709	1·877	3·27	1·94	2·06	3·316	4·30	4·187	4·05	5·47	2·12	4·32	5·37	3·454	5·785	6·55	6·81	6·78	5·43	N.W. & W.
May	3·428	3·567	2·965	3·04	3·50	3·95	5·066	4·92	4·100	4·91	5·32	3·99	5·46	5·30	7·221	7·466	8·62	8·08	8·04	7·67	S.W.
June	2·912	3·297	2·406	3·54	3·12	3·59	3·622	4·83	4·225	5·48	5·86	4·23	5·95	6·62	4·518	5·178	6·71	7·27	7·18	5·21	N.W.
July	·776	·775	·824	1·20	1·17	1·13	1·410	1·98	1·110	1·65	1·99	1·67	3·21	3·80	1·779	2·513	2·71	3·32	3·17	2·35	S.W.
Aug.	4·496	4·494	2·814	4·98	4·76	3·76	4·070	6·12	6·572	7·57	9·14	5·33	5·82	7·79	4·779	4·015	8·49	10·48	10·31	7·78	W.
Sept.	3·738	3·478	2·367	4·21	4·57	4·40	5·324	9·34	6·594	6·99	10·13	6·68	8·14	11·94	4·436	8·278	11·34	13·28	12·80	10·00	N.W.
Oct.	5·407	5·102	3·840	6·56	5·47	5·13	8·806	10·50	8·835	11·96	16·83	8·30	10·27	13·53	12·922	14·022	17·75	20·52	20·09	17·57	S.W. var.
Nov.	7·937	8·235	5·393	8·70	8·10	8·70	11·420	17·10	14·225	17·71	22·86	10·59	13·25	17·54	15·904	17·558	18·19	21·85	21·26	20·83	S.W.
Dec.	6·597	6·241	4·394	6·97	6·28	6·59	8·826	10·09	8·457	12·86	16·59	8·04	8·93	12·15	11·927	14·409	17·35	20·54	20·33	15·95	S.W. & S.E.
1847	42·921	42·023	30·713	47·80	42·55	44·45	58·286	80·13	66·296	82·32	106·25	58·66	74·93	96·34	78·004	93·338	112·95	120·24	126·80	106·21	S.W.
1846	49·134	.....	35·422	55·16	52·41	.....	67·678	83·87	79·249	96·47	121·90	.....	.....	106·93	77·719	110·329	127·40	143·51	.....	.....	.....
1845	49·207	.....	33·489	53·00	46·93	.....	62·202	76·88	69·542	87·48	124·13	.....	.....	108·55	76·305	121·008	136·00	151·87	.....	.....	.....
1844	36·723	.....	27·862	39·31	.....	.....	40·629	54·62	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

\* St. James's Church is forty-nine yards distant, in a direct line, from the gauge in my garden.

† In 1844, 1845 and 1846, the Ennerdale gauge was stationed at Bowness, about the middle of the lake; in 1847 the fall was measured at Gillerthwaite, about two miles above the head of the lake, and near the foot of Red Pike and the Pillar Mountain. During eight months of 1846 registers were kept at both stations, and the results show an excess of about one-ninth at the higher station.

\*\* The Roman Numerals at the head of the Table refer to corresponding numbers in the accompanying map of the Lake Districts, so that the position of any one of the gauges may be seen at a glance.

TABLE VIII.

Wet Days.

1847.	Whitehaven.	The Floss.	Cockermouth.	Keswick.	Loweswater.	Buttermere.	Wasdale.	Grasmere.	Langdale.	Troutbeck.	Bassenthwaite.	Seathwaite.	Stonethwaite.
January ...	13	15	15	14	13	14	14	15	15	10	11	13	14
February...	15	14	13	10	10	12	16	12	12	12	12	10	10
March .....	12	13	17	14	13	15	20	15	12	12	19	14	14
April .....	17	18	20	17	17	14	20	17	17	17	18	16	16
May .....	20	16	20	22	20	22	23	23	21	18	20	23	21
June .....	14	14	17	17	15	17	16	18	20	18	20	15	15
July.....	8	8	11	10	9	9	16	10	12	9	10	13	11
August ...	18	17	21	18	18	18	20	15	18	16	16	17	15
September.	20	17	22	24	21	21	24	22	23	21	21	23	23
October ...	14	15	16	18	17	17	17	19	17	18	14	19	17
November..	22	20	20	22	21	22	23	20	24	21	20	21	21
December..	18	16	18	18	16	18	24	18	18	16	18	18	18
1847	191	183	210	204	190	199	226	204	209	188	199	202	195
1846	200	208	234	213	198	216	234	202	213	194	.....	219	
1845	193	175	212	195	195	202	211	196	.....	180	.....	211	

TABLE IX.

Returns of the Mountain Gauges from March 1846 to November 1847 inclusive.

No.	XXI.	XXII.	XXIII.	XXIV.	XXV.	XIV.	XIII.	XXVI.	XVIII.	Prevailing winds.			
1846.	Sca Fell, 3166 feet above the sea-level.	Great Gable, 2925 feet above the sea.	Sparkling Tarn, 1900 feet above the sea.	Top of Styre Head Pass, 1290 feet above the sea.	Brant Rigg, 500 feet above the sea.	The Valley.  Wastdale, 160 feet.	Valley * on south side of Sca Fell, Eskdale, height unknown.	Summit of Seatoller Common, Borrowdale, 1334 feet.	The Valley, Seathwaite, 242 feet above the sea.	At the sea coast, two daily observations.	At Crummock Lake, two observations daily.	At Seathwaite, Borrowdale, one observation daily.	
	March.....	in. 6·51	in. 7·47	in. 14·94	in. ....	in. 10·35	in. ....	in. 14·20	in. 17·85	S.W.	S.W.	S.W.	
	April .....	4·39	4·83	5·38	.....	6·59	.....	7·53	7·70	N.E.	E.	S.E.	
	May .....	2·40	3·13	4·11	.....	3·65	.....	2·75	4·40	S.W. var.	W.	S. to W.	
	June .....	5·00	7·60	6·55	6·26	.....	5·33	5·70	6·42	S.W. var.	W. & S.W.	S.W.	
	July .....	14·38	16·87	22·73	17·76	.....	16·82	18·35	20·80	S.W.	S.W.	S.W.	
	August .....	7·05	8·65	12·03	11·03	.....	8·96	8·15	10·58	N.E.	S.E.	S.E.	
	September ..	3·22	3·32	5·06	4·22	.....	3·79	3·75	4·60	S.E.	S. to W.	W.	
	October .....	13·40	12·82	20·35	15·35	.....	15·75	17·42	25·43	S.W.	S.W.	S.E. & N.W.	
	November } to 1847 }	18·27	18·13	31·82	32·52	30·22	32·79	27·04	27·51	Variable. East and west, nearly equal.	Variable. East and west, nearly equal.	Variable. East and west, nearly equal.	Variable to N.W.
	April .....	6·16	5·56	7·59	7·56	5·96	5·30	5·46	7·13	8·08	S.W.	S.W.	S.W.
	May .....	5·05	6·57	8·13	7·12	5·84	6·62	5·95	5·71	7·27	N.W. & N.E.	N.W. & W.	N.W. & S.W.
June .....	3·25	3·10	4·15	3·66	2·65	3·80	3·31	2·50	3·32	S.W. & N.W.	S.W. & N.W.	S.W.	
July .....	8·39	7·90	12·00	10·22	7·48	7·79	5·82	10·38	10·48	W.	W.	W.	
August .....	8·75	9·22	12·43	10·92	9·03	11·94	8·14	12·06	13·28	N.W.	N.W. & W.	N.W.	
September ...	12·38	10·95	18·00	17·50	12·97	13·53	10·27	19·02	20·52	S.W.	S.E. to S.W.	S.W. var.	
October .....	9·55	10·86	22·64	20·00	12·50	17·54	13·25	18·07	21·85	S.W.	S.	S.W.	
In 21 months. {	128·15 From Nov. 1846. 71·80	136·98	207·91	185·74	86·65 From Nov. 1846.	170·55 From Nov. 1846. 99·31	79·24 From Nov. 1846.	180·23	223·64	S.W.	S.W.	S.W.	

\* Sca Fell lies between these two valleys, but is considered to belong to the Eskdale Range. Wastdale faces the north, and Eskdale Head the south side of the mountain.

† The gauge above Styre Head Pass was not erected till the end of May, and in order to avoid confusion in comparing the total receipts, it is thought best to estimate the quantity up to the time the other instruments were fixed.



The following Table exhibits the *particulars* of rain obtained from the Mountain Gauges, between November 1846 and April 1847 (inclusive), during which period the water in the receivers was more or less frozen. The *total* quantities only are inserted in the preceding Table.

TABLE X.

1846.	Sca Fell.	Great Gable.	Sparkling Tarn.	Stye Head.	500 feet.	Valley.	Seatollar Common.	Valley.
						Wastdale.		Seathwaite.
Nov. 30.	in.	in.	in.	in.	in.	in.	in.	in.
Dec. 31.	Solid.	Solid.	9·40	7·32	} 13·90† {	8·59	} 13·63 {	10·46
1847.	1·80	3·90	6·50	7·13		6·53		6·70
Jan. 31.	Solid.	Solid.	Solid.	Solid.	2·00	3·99	Solid.	6·29
Feb. 15.	Solid.	Solid.	2·70	4·80	.....	6·40 to 28th.	Solid.	8·27 to 28th.
March 8.	Solid.	Solid.	0·58	5·47	6·56	.....	7·71	
March 22.*	13·33	11·08	6·68	0·86	.....	1·91 to 31st.	1·02 to 31st.	2·53
April 10.	Solid.	Solid.	3·41	4·10	5·05			
April 30.	3·14	3·15	2·55	2·84	2·71	5·37	5·15	6·81
In six months	18·27	18·13	31·82	32·52	30·22	32·79	27·51	41·06

TABLE XI.—Showing the proportion which obtains between the quantity of rain deposited on the Mountains and in the Valley in the Summer months.

1846.	Sca Fell, 3166 feet.	Great Gable, 2925 feet.	Sparkling Tarn, 1900 feet.	Stye Head, 1290 feet.	The Valley.	Borrowdale.	
					Wastdale.	Seatollar Common, 1334 feet.	Valley. Seathwaite.
	in.	in.	in.	in.	in.	in.	in.
May .....	2·40	3·13	4·11	3·80	3·65	2·75	4·40
June .....	5·00	7·60	6·55	6·26	5·33	5·70	6·42
July .....	14·38	16·87	22·73	17·76	16·82	18·35	20·80
August .....	7·05	8·65	12·03	11·03	8·96	8·15	10·58
September .....	3·22	3·32	5·06	4·22	3·79	3·75	4·60
October .....	13·40	12·82	20·35	15·35	15·75	17·42	25·43
1847.							
May .....	6·16	5·56	7·59	7·56	5·30	7·13	8·08
June .....	5·05	6·57	8·13	7·12	6·62	5·71	7·27
July .....	3·25	3·10	4·15	3·66	3·80	2·50	3·32
August .....	8·39	7·90	12·00	10·22	7·79	10·38	10·48
September .....	8·75	9·22	12·43	10·92	11·94	12·06	13·28
October .....	12·38	10·95	18·00	17·50	13·53	19·02	20·52
In twelve months..	89·43	95·69	133·13	115·40	103·28	112·92	135·18

TABLE XII.—Showing the proportion in the Winter months.

1846.	Sca Fell.	Great Gable.	Sparkling Tarn.	Stye Head.	The Valley.	Borrowdale.	
						Seatollar Common.	Valley.
	in.	in.	in.	in.	in.	in.	in.
March .....	6·51	7·47	14·94	.....	10·35	14·20	17·85
April .....	4·39	4·83	5·38	17·82	6·59	7·53	7·70
November ..... to 1847. }	18·27	18·13	31·82	32·52	32·79	27·51	41·06
April .....							
November .....	9·55	10·86	22·64	20·00	17·54	18·07	21·85
In nine months ...	38·72	41·29	74·78	70·34	67·27	67·31	88·46

\* March 22, the gauges were free of ice; on the 31st they were again frozen up.

† Estimated in the same proportion as the other months bear to the valley, this gauge not being erected till December 31st, 1846.

TABLE XIII.  
Temperature at Seathwaite, taken by Self-registering Thermometers made by WATKINS and HILL.

1847.	Absolute		Mean of maximum.	Mean of minimum.	Mean at 4 feet.	Mean at 9 <sup>h</sup> A.M.	Thermometer on grass.				Prevailing winds.	At Crummock Lake.	At the Coast.
	Maximum.	Minimum.					Mean.	Radiation.					
								Maximum.	Mean.				
January .....	46.5	20	38.19	31.41	34.80	34.71	°	°	°	S.W.	S.E.	S.E.	
February .....	50	20	39.46	30.19	34.82	34.25	°	°	°	N.W.	Variable.	Variable.	
March .....	57	21	45.71	35.60	40.65	39.82	°	°	°	N.E. to S.W.	S.E.	S.	
April .....	56	25	47.44	35.83	41.63	41.90	18	14	5.63	N.W. & W.	S.W. & N.W. var.	S.W. & N.W. var.	
May .....	72	37	57.67	46.87	52.27	51.90	30.4	15.5	6.44	S.W.	S.W.	S.W.	
June .....	81	40	65.18	50.96	58.07	57.95	30.5	19.5	9.03	N.W.	N.W. & W.	N.W. & N.E.	
July .....	80.5	51	72.16	57.45	64.80	64.98	38	20	10.27	S.W.	S.W. & N.W.	S.W. & N.W.	
August .....	73	38.5	65.67	51.25	58.46	58.12	32	14	6.75	W.	W.	W.	
September .....	63	31.3	56.78	45.16	50.97	50.91	26	9.5	4.79	N.W.	N.W. & W.	N.W.	
October .....	64	34	53.72	43.51	48.61	47.88	27	10	4.71	S.W. var.	S.E. to S.W.	S.W.	
November .....	56	20	49.55	41.06	45.30	45.26	17	8	3.20	S.W.	S.	S.W.	
December .....	54	21	43.19	35.22	39.20	38.93	15	8	3.15	S.W. & S.E.	S. & S.E.	S.E. & S.	
Means at { Whitehaven. {	62.7	29.9	52.89	42.04	47.46	47.21	°	°	°	S.W.	Westerly.	S.W. var.	
Difference ...	0.5	3.8	0.96	1.46	1.22								

*Note.*—The Lake District gauges are 5 inches in diameter ; they are all of the same form and construction, and are elevated about 18 inches above the surface. [During 1844, 1845 and part of 1846, they were raised only 6 inches above the ground : in the course of the latter year they were altered to their present height. From a series of daily observations made in 1847 (vide Table) at Seathwaite, it appears that at 18 inches a gauge receives about  $2\frac{1}{4}$  per cent. less rain than at 6 inches above the surface.] The funnel rims are of stout sheet brass, so that the apertures cannot readily lose their circular form. The metres (HOWARD's) were all made by Mr. BATE of the Poultry, London. The rain (except at five stations) is read off daily at nine o'clock A.M., and each day is accounted wet in which any appreciable deposition is found in the instrument. The rain at St. James's Church Steeple, at Gatesgarth and Eskdale Head, is measured weekly ; and at Round Close and Gillerthwaite once or twice a month.

The gauges at and in the vicinity of Whitehaven, are 8 inches in diameter, and the metres show distinctly each separate thousandth of an inch.

Before concluding to use a gauge of 5 inches diameter for the Lake Districts, I placed one of HOWARD's gauges in my garden, within a few yards of the 8-inch pluviometer, and measured the contents of each every morning for six months. From the 1st of August 1843 to the 31st of January 1844, the gauge of 8-inches aperture received 23·997 inches, and the 5-inch gauge 23·765 inches. I attribute this trifling difference to the circumstance of the larger gauge-metre being graduated to  $\frac{1}{1000}$ th of an inch, whilst the smaller only indicates  $\frac{1}{100}$ th, or half a hundredth of an inch.

#### *Remarks.*

1845.—At Seathwaite, there have been thirty-one days in which the fall was between 1 and 2 inches ; fifteen days between 2 and 3 inches ; five days between 3 and 4 inches ; one day between 4 and 5 inches, and one day between 6 and 7 inches.

On the 27th of November, at nine A.M., there was measured at Seathwaite 6·62 inches, and on the 26th and 27th nearly 10 inches, being unquestionably the greatest quantity of rain which has ever been recorded in the same period in the British Islands.

At Langdale Head, in Westmoreland, the fall on the 27th was 6·28 inches, and on the 26th and 27th nearly 9 inches.

On the 22nd of April 1792, Dr. DALTON measured 4·592 inches at Kendal, a remarkably wet locality ; but I find on inquiry that the greatest fall at that place in twenty-four hours, during the present century, is rather short of 3 inches.

Of the total quantity of rain measured in the Vale of Borrowdale in 1845, 106·58 inches fell in the six months of January, March, August, October, November and December ; and nearly 46 inches in the two latter months. The quantity in December, at some of the stations, is more than falls at many places in England during a whole year.

The fall at Seathwaite is more than three times the quantity at Whitehaven, one

of the wettest towns in the kingdom. It exceeds the fall at Leeds by six times ; at Culloden by five and a half times ; at Doncaster and Highfield House, Nottinghamshire, by five times ; at Cirencester and Arbroath by five and a quarter times, and at Makerstoun near Kelso, by more than seven times.

Seathwaite exceeds Doncaster in January by fifteen times, in November by twenty-one times, and in December by nine and a half times. It exceeds the quantity at York in January by 16 inches, or twenty times ; in March by nine times, and in November by twenty times. It exceeds Dublin in March by fourteen times, in April by thirteen times, in October by five times, and in November by seven times.

1846.—At Seathwaite there have been thirty-six days in which the quantity of rain was between 1 and 2 inches ; six days between 2 and 3 inches ; five days between 3 and 4 inches ; one day between 4 and 5 inches, and one day between 5 and 6 inches. At Langdale Head there have been thirty-eight days of the first, five days of the second, and four days of the third class ; and one day wherein the fall exceeded 4 inches. The rain at Seathwaite on the 3rd and 4th of March amounted to 6·86 inches ; and on the 9th and 10th of October the fall was upwards of 9 inches. On three days of the latter month there fell 12·17 inches.

Of the total fall of rain at Seathwaite in 1846 (143·518 inches), 103·24 inches fell to the share of January, February, March, July, August and October ; the other six months received much less than in the previous year. In November and December 1845, there fell  $45\frac{3}{4}$  inches ; in the corresponding months of 1846, the fall but slightly exceeds 17 inches. The table shows, that whilst the lake district stations generally have received *more* rain than in 1845, the deposit in the five wettest localities is somewhat *less* than in the previous year.

1847.—A glance at the first table will show that during the year 1847 much less than an average quantity of rain has fallen\* ; indeed, had it not been for the enormous downfall in October, November and December, the past year would have been one of the driest on record in this part of the country. At the close of September the fall in the lake districts was from one-third to one-fourth less than the average of the two preceding years : thus, Seathwaite was 29·59 inches, or nearly one-third ; Wastdale 18·76 inches, or one-fourth ; and Gatesgarth 34·96 inches, or *more* than one-third short of the average of 1845 and 1846, for the same period. But the year 1847 is memorable for the remarkable fact, that as much or nearly as much rain fell in the last three months as descended during the other nine months of the year. At the following stations, the quantity from October to December inclusive is considerably more than one-half of the whole annual depth.

	January to October.	October to December.
Buttermere . . . . .	39·79 . . . . .	42·53
Gatesgarth . . . . .	49·97 . . . . .	56·28
Troutbeck . . . . .	37·25 . . . . .	40·75
Stonethwaite . . . . .	51·86 . . . . .	54·35

\* With some few exceptions the deficiency appears to have been general over the kingdom.

At Seathwaite there have been thirty-two days wherein the quantity of rain was between 1 and 2 inches, five days between 2 and 3 inches, five days between 3 and 4 inches, one day between 4 and 5 inches, and one day between 5 and 6 inches. At Langdale Head there have been thirty days of the first, three days of the second, and five days of the third class (3 to 4 inches).

There was hail in the lake districts on the 8th of June and on the 25th of July. The last traces of snow disappeared from the mountains on the 1st of June, and the first appearance of hoar frost was on the 27th of September.

I purposely postpone any remarks on the temperature of the lake districts till the next report, when I hope to make some extensive comparisons with other and widely different localities. The temperature of these valleys is much higher than is commonly imagined. The observations both in 1846 and 1847 were taken with great care, and I have no doubt of their correctness. The radiation from the earth is much greater in summer than at the coast; but in winter it appears to be so exceedingly small, that I have thought it best to omit the results for those months in the table till future observations have proved their accuracy or otherwise.

### *The Mountain Gauges.*

The mountain gauges are on pretty much the same construction as those in the valleys, but the receivers are much more capacious, being calculated to hold nearly 80 inches of water. These gauges are, with one exception, stationed on the high mountains surrounding the vale of Wastdale.

Sca Fell, the highest mountain in England, stands on the south, and Great Gable on the north side of the valley. The gauge above Sty Head Tarn is on the shoulder of the Gable at the eastern extremity of the vale: Sparkling Tarn is about 600 feet above the top of Sty Head Pass, in a southerly direction, and 1260 feet higher, bearing south-west, are Sca Fell Pikes.

The bearings of the several stations from the gauge at Wastdale Head are as follow:—Sca Fell, S.; Gable, N.N.E.; Sty Head, N.E.; Sparkling Tarn, E. by N.; and Seatollar Common in Borrowdale, N.E., distant four and a half miles in a direct line.

The gauges on Sca Fell, Gable and Seatollar, are on the extreme summits of these mountains, and the whole of the instruments are freely exposed to the action of wind and rain from almost every point of the compass.

Appended to the tables for 1846 I find the following remark:—"It would be premature, from the scanty data before me, to draw any decided inference as to the gradation in the quantity of rain at these great elevations above the sea. But it seems probable that in mountainous districts the amount of rain increases from the valley upwards, to an altitude of about 2000 feet, where it reaches a maximum; and that above this elevation it rapidly decreases." The Table for 1846 exhibited the rain-fall of the summer months only, but the additional returns of 1847, obtained in every variety of season, confirm the above deductions in every essential particular,

so that we may fairly assume the combined results to be indicative of a physical law, so far at least as relates to the particular locality in question. Thus, in twenty-one months,

The Valley . . . .	160 feet above the sea, has received 170·55 inches.		
Stye Head . . . .	1290	„ „	185·74 „
Seatollar Common .	1334	„ „	180·23* „
Sparkling Tarn . .	1900	„ „	207·91 „
Great Gable . . .	2925	„ „	136·98 „
Sca Fell . . . . .	3166	„ „	128·15 „

An apparent exception to this law occurs in the gauge stationed at Brant Rigg, about midway between the top of Stye Head and the vale of Wastdale, at an estimated height of 500 feet above the sea, and which in last year has received about one-eighth, or twelve and three quarters per cent. less rain than the valley. This is the only one of the gauges situated on the *slope* of a mountain; it is on the windward side, and I imagine that in such a position, eddies or counter currents are produced in windy weather, which cause a less quantity of water to be deposited in the instrument than is due to the elevation. We know that all sloping roofs, from the same cause, materially diminish the receipts of rain-gauges.

It will be observed that the amount of water received by the Seatollar gauge is invariably less than the deposit in the adjacent vale of Seathwaite, and the deficiency is pretty equable in every month of the year. I am unable to give any satisfactory reason for this apparent anomaly, or to account for the very great excess of rain in this valley over all others in the lake districts. As the gauge on Seatollar is two or three miles distant in a direct line from the others, the near approach of its receipts to the Stye Head gauge, about the same elevation, is rather remarkable. In 1846 the Seatollar exceeded the Stye gauge in quantity, which it should do if the assumed height be correct.

By referring to the table for the summer months, we find that between the 1st of May and the 31st of October, the gauge at 1290 feet has obtained nearly twelve per cent. more rain than the valley; at 1334 feet, nine and a half per cent. more; at 1900 feet, twenty-nine per cent. more; at 2928 feet, seven and a half per cent. *less*; and at 3100 feet, thirteen and a half per cent. less than the valley.

In the winter months (November to April inclusive) the gauge at 1290 feet has received four and a half per cent. more than the valley, and at 1334 feet exactly the *same quantity* as the valley; at 1900 feet, eleven and a quarter per cent. more; at 2928 feet, thirty-eight and a half per cent. *less*; and at 3100 feet, forty-two and a half per cent. *less* than the valley. The difference in the proportion to the valley between the summer and winter half-year, as shown in the tables, is rather startling. When much snow falls, doubtless a considerable proportion is lost to the instrument, either

\* The height of Seatollar Common has not been correctly ascertained.

by its being blown out of the funnel, or by the orifice getting choked up. But I do not think that this cause alone is at all adequate to account for the great comparative deficiency in the winter months, for there was very little snow on the mountain tops during the winter of 1846–47, less I am told by one of the oldest residents in the Fell Dales, than he almost ever remembers. At Whitehaven we had no snow worth naming, except on the night of the 23rd of December, when it covered the ground to the depth of nearly an inch, but disappeared in the course of the ensuing morning.

The late Mr. CROSTHWAITE of Keswick, by means of marks on the side of Skiddaw, and with the assistance of a telescope at his residence, made two or three daily observations on the height of clouds for several years, and it is clearly proved by his tables, that the clouds are lowest in the three first and three last months of the year\*. Moreover, Dr. DALTON affirms in his "Meteorology," that the clouds are seldom a mile high (or little more than  $1\frac{1}{2}$  time the altitude of Sca Fell) in this climate in winter. Now the Doctor here probably alludes to, or at least includes, the most elevated clouds, such as the cirri, and some varieties of the cirrostratus. But there can be no doubt, that between the months of November and March, the under surface of the nimbus or rain-cloud (the lowest except the stratus) is *far* below the tops of our highest mountains, and I have reason to believe, not unfrequently, its upper surface also: when this is the case, the gauges on Sca Fell, Gable, &c. will receive no rain at all, when it is descending abundantly in the valleys beneath. I have a well-authenticated instance of such an occurrence, even in the middle of summer. On the 5th of July 1846 (the hottest day in the year) this county was visited by a dreadful storm of thunder, lightning, hail and rain, which continued from two to half-past four o'clock in the afternoon. Two gentlemen who happened to be on the top of Skiddaw during this storm, state that, whilst the rain was pouring down in torrents in the valley, not a drop fell on the summit of the mountain. In this elevated position the sky was clear, and the atmosphere calm and untroubled, when below them the elemental war was raging with the most terrific fury. The spectators describe the scene as awfully grand, beyond conception. The lowness of the rain-cloud at this season is, I apprehend, the principal cause of the small quantity of rain in proportion to the valley, during the winter as compared with the summer months.

I shall conclude this paper with a few general remarks.

In the year 1836 or 1837, Mr. BECK of Esthwaite Lodge, about two miles to the westward of Windermere Lake, began to register the amount of rain in that neighbourhood, and between 1837 and 1844, the annual quantity varied from 60 to 86 inches. In 1843, Mr. JEFFERIES obtained 90 inches at Grasmere. The results at Esthwaite and Grasmere were received with astonishment by meteorologists, not unaccompanied by some degree of suspicion as to their correctness. Indeed it was with the view of removing all doubt on the matter, that in the year 1844 I was

\* DALTON'S Meteorology, 1796.

induced to begin the present series of experiments on rain amongst the hills of Cumberland. Yet 90 inches would now be thought a small quantity for some parts of the Lake District, even in a year of drought!!

I am frequently asked by persons unacquainted with such matters, what beneficial end I expect such a series of experiments to lead to, and what information I have gained in return for my loss of time and trouble. To this question I may reply, they have shown us, that at least 60 inches more rain is deposited in England than we were previously aware of; that 150 inches sometimes descends in the Lake District in a year, more than falls in most parts of the tropics with which we are acquainted, and sufficient to drown standing, two of the tallest men in Great Britain, one on the top of the other. They have further informed us, that  $6\frac{1}{2}$  perpendicular inches of water is sometimes precipitated from the atmosphere in twenty-four hours, and 10 inches in forty-eight hours, a quantity which would be thought large for any two consecutive months in most parts of England. We have further ascertained that the almost incredible depth of 30 inches occasionally descends in a single month; a fall nearly equal to the calculated average for all other parts of England in a year\*. The experiments have, in short, enabled us to collect a number of new and curious facts, bearing on the quantity and very unequal distribution of rain in this island. We have also ascertained, with a high degree of probability, the law of the gradation in the amount of rain, at various intermediate points, between the valleys and the tops of our highest mountains.

A little consideration will greatly lessen our surprise at the enormous quantities of water deposited in the hilly districts of Cumberland and Westmoreland, and at the consequent unequal distribution of rain in the climate of Great Britain. To those unacquainted with these localities, it may be briefly stated, that the lake district valleys radiate from a series of mountains of slate and primitive rock, having the Gable, 2928 feet in height, as a nucleus or central point, and in the immediate vicinity of which are Sca Fell and Pillar, of the respective elevations of 3166 and 2893 feet; and Great End, Bowfell and Glaramara, not much inferior in altitude. These mountains are distant only about thirteen or fifteen miles, in a direct line from the Irish Channel, and as no hills intervene, they are consequently fully exposed to our wet and prevailing winds, which are the south-west.

The warm south-westerly current arrives at the coast loaded with moisture obtained in its transit across the Atlantic: now our experiments justify us in concluding, that this current has its maximum density at about 2000 feet above the sea level; hence it will travel onward until it is obstructed by land of sufficient elevation to precipitate its vapour; and retaining a portion of the velocity of the lower parallel of latitude whence it was originally set in motion, it rapidly traverses the short space of level

\* This astonishing quantity fell at Seathwaite in February 1848, in twenty-five days, on several of which the amount was very trifling. The gauge at 6 inches above the surface received 30·55 inches, and that at 18 inches 29·98, or 30 inches nearly.



country, and with little diminution of its weight or volume; but on reaching the mountains, it meets with a temperature many degrees lower than the point at which it can continue in a state of vapour; sudden condensation consequently ensues in the form of vast torrents of rain, which in some instances must descend almost in a continuous sheet, as when 9 or 10 inches are precipitated in forty-eight hours.

When we reflect that a warm moist current, perhaps only  $3^{\circ}$  or  $4^{\circ}$  above the point of saturation, in coming in contact with the mountain ridge, probably meets with a stratum of air  $10^{\circ}$  or  $15^{\circ}$  lower than its own inherent temperature, we shall cease to marvel that such quantities as four or five, or even six perpendicular inches of water should be deposited in these localities in the course of a few hours. The mountains are, in fact, huge natural condensers, destined to force from the atmosphere the mighty volumes of water requisite for the supply of our lakes and rivers.

I have before stated that I am unable to offer any satisfactory reason for the great excess of rain at Seathwaite over all the other valleys; judging from its situation, I should, *à priori*, have looked for the greatest fall at Wastdale Head, as it is surrounded by the highest mountains, and the valley opens out fairly to the south-west. But the maximum quantity is found to obtain, not where theory would indicate, but in the very identical spot where it is most required,—in the vale of Borrowdale, which affords the principal supply of water to the extensive and picturesque lakes of Derwent and Bassenthwaite; thus adding one more to the multitudinous instances which surround us, of the wonderful adaptation of external nature to the physical wants and requirements of man.

*Whitehaven, March 15, 1848.*