Cumulative Temperatures

IN reference to my letter upon the above subject, which was published in your columns of February 21 last, I have received from Prof. de Candolle, of Geneva, a communication dated March 11, in which he calls attention to the fact that in his "Géographie Botanique raisonnée," which was published as far back as the year 1855, he recorded the suggestion (made by himself some ten years previously) of the employment of an uncompensated pendulum fitted with a suitable registering apparatus for the determination of cumulative temperatures in connection with the application of meteorology to agriculture and to the geography of plants.

In the above work (vol. i. pp. 58 and 59) the following passage occurs:—

"Les chiffres les plus importants à connaître pour les applications de la météorologie à l'agriculture et à la géographie botanique sont, pour chaque localité, les sommes de température au dessus de $+1^{\circ}$, $+2^{\circ}$, de $+3^{\circ}$, etc., par année, saison, mois ou fraction de mois.

"Pourrait-on obtenir ces valeurs directement par un instrument spécial, qui dispenserait de recourir à des calculs compliqués, souvent impraticables, dans le système actuel des observations météorologiques? C'est une question que je soumetts aux physiciens. Elle m'a préoccupé depuis longtemps, mais je suis loin de posséder les connaissances théoriques et pratiques nécessaires pour arriver à une solution. J'entrevois la possibilité de construire deux sortes d'instruments qui répondraient aux conditions désirées; je les mentionne sans pouvoir indiquer les détails d'exécution.

"L'un de ces instruments serait la pendule-thermomètre de M. Edmond Becquerel, modifié de telle sorte que les battements par une température inférieure à 0° , ou ceux inférieures à $+1^{\circ}$, à $+2^{\circ}$, etc., ne seraient pas comptés."

"Un autre système serait celui de thermomètres graphiques marquant les températures supérieures à tel ou tel degré, et seulement celles-là."

To this the following foot-note was added:—"Il y a plus de dix ans je fit des démarches auprès de deux astronomes, M. Gautier, à Genève, et M. Arago, à Paris, pour appliquer la pendule à la mesure des températures. Je proposais une pendule aussi dilatée que possible sous l'action de la température et un compteur adapté à l'instrument. . . Les honorables savants auxquels je m'étais adressé pensèrent qu'il serait trop difficile de soustraire l'instrument à diverses causes d'erreurs."

From the above, which was written twenty-three years ago, it is clear that to the eminent botanist must be accorded the merit of priority not only of the suggestion but also of the publication of the idea of the method of averaging temperatures by observations of the pendulum, while to Mr. Stanley must be given the credit of embodying that idea in a practical form and constructing an instrument based upon the principle.

St. Leonards-on-Sea, March 16

CONRAD W. COOKE

The Wasp and the Spider

I HAD anticipated in my own mind Mrs. Hubbard's suggestion, and only the great pressure on your space prevented my meeting it in my previous letter. In the first place, my recollection is that the spider was of a kind that spins no web; like our own grey hunting spider, familiar in the summer on walls and palings. In the next place no species of spider, except the gossamers, habitually leaves this fine line behind it. It is in all cases a voluntary act, preceded by a perceptible pause, and pressure downwards of the extremity of the body to attach the end, whether for suspension, or in the process of forming the web. Even the gossamers are no exception to this rule; only in their case the line, in summer and autumn, is more continuously run out as a point of departure for their mysterious aerial flights. A house-spider, for instance, as he runs across the floor or across your hand, leaves no fine line behind him. The tiny gossamer has an amazing command of the material, but in the larger, web-spinning kinds it is far from inexhaustible, and, at all events, an apparently useless waste is not in the ordinary economy of nature. Moreover, in the case in question the spider was keenly aware he was pursued, and would not willingly leave so far a clue on his track. Mr. Merlin, who is on the list for 1878 as our consul for the Pireus, is, however, a competent observer, and could settle the question.

HENRY CECIL

Bregner, Bournemouth, March 23

SUN-SPOTS AND RAINFALL

BY the overland mail which arrived here on January 12, I received, through the courtesy of Dr. W. W. Hunter, two copies of a pamphlet on "The Cycle of Drought and Famine in Southern India," a copy of the *Nineteenth Century* for November, and a copy of a letter on "The Rainfall in the Temperate Zone in Connection with the Sunspot Cycle," published in *NATURE* (vol. xvii. p. 59).

Having previously read notices of the pamphlet and being desirous to see it, I requested its author to favour me with a copy. His rainfall cycle for Madras was, so far as I could learn from newspaper reports, identical with a cycle which I had discovered long before. In my official report for 1875, which was printed and circulated in 1876, I gave a *résumé* of the results at which I had arrived from 1872 down to the close of 1875, and stated that an examination of returns from 144 stations in different parts of the world, as well as of the variations in the levels of European rivers, had led me to the conclusion that there was a rainfall cycle of the same duration as the sunspot cycle and nearly coincident with it, both the sunspots and the rainfall attaining a minimum in the eleventh, first, and second years of the cycle, and a maximum in the fifth year. Hence when I learned from an abstract of Dr. Hunter's results for Madras that in his "cycle of eleven years both the sunspots and the rainfall reach their minimum in the group consisting of the eleventh, first, and second years, and that both the rainfall and the sunspots there increase till they both reach their maximum in the fifth year," I was curious to know how his cycle had been made out; for although I had not the Madras rainfall for each year from 1813 to 1872, yet from the falls in the years of maximum and minimum sunspots which I got in the *Proceedings and Transactions* of the Institution of Civil Engineers (vol. xxxii.), I inferred that the Madras rainfall was not quite so favourable to my hypothesis as the rainfalls of some other places. As, however, I might be wrong, I applied for a complete table of the Madras rainfall, but without success.

A remarkable rainfall cycle for Bombay, nearly coincident with the sun-spot cycle, had been previously ascertained, and a similar cycle, though not so well marked, had also been found by comparing the yearly mean rainfalls of Anjarakandy, Bombay, Calcutta, and Nagpur with Wolf's relative sun-spot numbers.

I have now the whole history of the Madras cycle before me. The author of the pamphlet says that after many experiments he hit upon a method of working out a cycle. This method consisted in commencing with 1876, taking backwards, as far as the register extended, periods of eleven years each, and then finding the mean rainfall for each series of years in the common period.

The results obtained for Madras by this method are to a considerable extent in conformity with those which I had found for different countries; but there are discrepancies, one of the most remarkable of which is that the rainfall in the second year of Dr. Hunter's cycle is greater, instead of less, than the mean rainfall. Still there is a certain amount of coincidence. But as the method used by Dr. Hunter—and I would call special attention to this point—is different from the one by which I found my cycle, his results and mine are not comparable.

The sun-spot cycle being one of about eleven years, and the maximum epoch occurring, on an average, 37 years after the previous minimum, and the next minimum 74 years after the maximum, I found by experience that the best way of comparing the rainfall and the sun-spots was to start either from a maximum or a minimum year, and then to take the proper number of years before and after the epochal year. Commencing with a maximum year, for instance, I took five years before it and seven

years after it, or thirteen years in all. Then, with the view of reducing the effects of the so-called non-periodic variations, I took a mean of the rainfall in the first and third of the thirteen series, and a mean of that mean and of the rainfall in the second series, and so on. This gave me eleven new means, which I called the "mean cycle." Again, starting with a minimum year, I took eight years before it and four years after it, and found eleven other new means in the same way. To each set of results, or to a combination of both

of them, I then applied interpolation formulæ, and found a well-marked coincidence between the sun-spot and rainfall variations.

As the sun-spot cycles are not all of the same length, it is evident that by starting from any one year and going backwards over a long period, always using the same fixed number, a maximum and a minimum year might fall into the same group.

Let me, by an example, explain my method more fully. I take the Madras rainfall:—

TABLE I.—*Rainfall Cycle at Madras.*

Years.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
	in.	in.	in.	in.	in.	in. max. years.	in.	in.	in.	in.	in.	in.	in.
1811-23	—	—	45'11	32'41	56'00	41'16	63'56	76'25	36'33	70'01	47'13	59'61	26'62
1824-36	33'72	56'05	60'71	88'41	37'89	36'87	32'43	44'35	18'45	37'11	39'00	41'47	44'76
1832-44	18'45	37'11	39'00	41'47	44'76	49'26	52'33	53'07	58'65	58'32	36'48	50'28	65'36
1843-55	50'28	65'36	38'05	79'81	80'99	54'76	39'81	36'88	64'32	72'69	35'82	43'20	32'32
1855-67	32'32	46'99	52'95	48'50	55'14	27'64	37'19	38'18	54'61	47'23	41'64	51'39	24'37
Means	33'69	51'38	47'17	58'12	54'96	41'94	45'06	49'75	46'47	57'07	40'01	49'19	38'69
Mean Cycle	—	46'12	50'96	54'59	52'49	45'97	45'55	47'75	49'94	50'15	46'57	44'52	—
Rainfall Variation	—	2'48	2'36	5'99	3'89	2'63	3'05	0'85	1'34	1'55	2'03	4'08	—
Sun-spot Variation	—	32'3	19'2	1'1	30'2	40'0	29'8	11'3	1'2	12'8	21'1	23'6	—
Years of Cycle	—	1	2	3	4	5	6	7	8	9	10	11	—

It will be seen that the individual years of maximum sunspots, 1816, 1829, 1837, 1848, and 1860, are all in the same vertical column, and that all the years of minimum sun-spots, except 1810, contribute to the formation of the beginning and end of the cycle. No doubt it would have been better to have placed 1836 farther in advance, but this would have altered the position of the maximum year 1829.

The results given by the above method show a double oscillation of the Madras rainfall during the sun-spot period, and I see (NATURE, vol. xvi. p. 333) that Mr. J. Allan Broun has found such an oscillation for Trevandrum as well as for Madras, and this may be a characteristic of the rainfall of the whole of Southern India. We have,

however, evidence of a single rainfall oscillation for other parts of India. Even Mr. Blanford now admits that there is a periodic variation underlying all irregularities and more or less coincident with the sun-spot variation.

In consequence of the method adopted by Dr. Hunter the years of maximum sun-spots, in place of being all in the same group, are spread over three or four of the groups from which he derived his mean cycle, and it is probably owing to this that he missed what, I think, is the real character of the rainfall cycle at Madras, as shown in Table I. The annual average rainfall for each year of his cycle, together with the deviations from the mean, is as follows, and it will be seen that his cycle is very different from the one given by my method:—

Years of Cycle.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
Average Rainfall ...	49'15	35'00	49'08	49'17	58'33	50'95	50'37	54'35	52'88	45'16	37'03
Rainfall Variation ...	+0'84	-13'31	+0'77	+0'86	+10'02	+2'64	+2'06	+6'04	+4'57	-3'15	-11'28

According to Dr. Hunter's cycle, the rainfall of Madras was in excess in the fifth year to the extent of *ten* inches, whereas, according to mine, it was nearly *three* inches in defect. He takes, it is true, the years 1868-76, which I do not take, preferring to wait till I get the rainfall of 1877; but although 1870, which he puts down in his fifth group, was a very wet one, the double oscillation still exists, one of the minima occurring soon after the sun-spot maximum.

I must now come to Dr. Hunter's letter in NATURE (vol. xvii. p. 59). But, first of all, I may be excused for saying that I do not think some remarks he made about a periodicity of cyclones in a former letter (vol. xvi. p. 455)

were altogether calculated to put the matter in its proper light. He says (p. 456):—"M. Poëy called the attention of the French Académie des Sciences to the subject five years ago, and published, as far back as 1873, a list of hurricanes in the West Indies from 1750 to 1873, in support of his views. Dr. Meldrum has worked the same question as regards the [East] Indian Ocean." Now if these words are meant to convey the impression that M. Poëy preceded me, and that I followed with the cyclones of the Indian Ocean, all I can say is that M. Poëy himself gave a different version of the matter.

In his second letter (vol. xvii. p. 59) Dr. Hunter states

(1) that the evidence with respect to the European rainfall may be considered as "against a well-marked periodicity," and (2) that the result of a "systematic inquiry (by himself) into the American rain-returns altogether fails to establish the existence of a common cycle, so far as concerns the temperate zone." On each of these points I beg to make a few remarks.

The evidence on which Dr. Hunter bases his statement as to the European rainfall is derived (1) from an examination by Mr. Baxendell, for a short period, of the rainfall at one English station, (2) from an examination by the late Dr. Jelinek of fourteen stations on the Continent, from 1833 to 1869, and (3) from a comparison of the levels of the Elbe, Rhine, Oder, Danube, and Vistula, with the sun-spots for six cycles, a comparison which Dr. Hunter ascribes to Herr Gustav Wex, but which I believe is due to another.

Now, the evidence is much more extensive. Instead of being based on one British station and fourteen stations

on the Continent, it is based on more than fifty British stations and more than forty stations on the Continent, and, taken with the evidence furnished by the rivers, it is, in my opinion, conclusive.

As to the American rainfall, an examination of thirty-four returns has given me much more favourable results than those Dr. Hunter has got from twenty-two stations, and I have little doubt that he will, as he extends his investigations, also find favourable results; but I think he must first adopt a method different from the one he used for Madras.

In support of my conclusion that the rainfalls of Europe and America are subject to a periodicity which closely corresponds with the sunspot periodicity, I will for the present only submit to your readers two tables, the one showing the general results for Great Britain, the Continent of Europe and America, and the other the results for one station in each of these countries, namely Edinburgh, Paris, and New Bedford.

TABLE II.—Comparison of the Variation in the Sun-spot Area with the Variations in the Rainfalls of Great Britain, Continent of Europe, and America, from 1824 to 1867 inclusive.

Years of Cycle.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Sun-spots	—	—	+	+	+	+	+	—	—	—	—
Rainfall of Great Britain	31.7	19.5	3.5	28.8	39.5	29.5	10.4	4.9	14.8	21.2	19.4
Rainfall of Continent of Europe	—	—	+	+	+	+	+	+	+	—	—
Rainfall of America	2.22	1.67	0.04	1.16	1.05	1.46	1.28	0.89	0.43	0.73	1.03
Mean Rainfall Variation	—	—	—	—	—	—	—	—	—	—	—
	0.76	1.73	1.22	0.44	1.18	0.97	1.08	0.60	0.45	0.36	0.62
	—	—	+	+	+	+	+	+	+	—	—
	2.73	0.88	0.91	0.53	0.24	1.34	2.03	0.84	0.27	0.66	1.24
Mean Rainfall Variation	—	—	—	+	+	+	+	+	—	—	—
	1.90	1.43	0.09	0.71	0.82	1.26	1.46	0.78	0.10	0.65	0.55

The above results have been obtained in the manner in which I obtained the rainfall variation in Table I. For Great Britain the number of stations is 54, for the Continent of Europe, 42, and for America, 32.

TABLE III.—Comparison of Variation in Sun-spot Area with Variations in Rainfalls of Edinburgh, Paris, and New Bedford, from 1824 to 1867 inclusive.

Years of Cycle.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Sun-spots	—	—	+	+	+	+	+	—	—	—	—
Rainfall of Edinburgh	31.7	19.5	3.5	28.8	39.5	29.5	10.4	4.9	14.8	21.2	19.4
Rainfall of Paris	—	—	+	+	+	+	+	—	—	—	—
Rainfall of New Bedford	3.02	1.66	0.64	2.50	3.45	2.86	0.64	0.27	0.91	2.36	0.56
Mean Variation of Rainfall	—	—	—	—	—	—	—	—	—	—	—
	0.25	0.61	0.30	1.27	2.22	1.90	1.49	0.84	1.42	0.94	0.48
	—	—	+	+	+	+	+	+	+	—	—
	3.07	1.03	0.69	0.32	0.19	1.38	3.47	2.87	0.32	1.42	0.68
Mean Variation of Rainfall	—	—	—	+	+	+	+	+	—	—	—
	2.11	1.10	0.54	1.15	1.83	3.05	1.87	0.59	0.88	1.57	0.25

It will be observed (see Table I.) that the variation in the Madras rainfall is not nearly so favourable as the variations for Edinburgh, Paris, and New Bedford.

What I have given here is but a small portion of the evidence in favour of a rainfall cycle. Having worked at

the subject for six years, I have concluded that the whole evidence is as satisfactory as the evidence of a connection between sun-spots and terrestrial magnetism.

C. MELDRUM

Mauritius, February 1

JULIUS ROBERT VON MAYER

SEVERAL years ago (vol. v. p. 117) we published a paper by Prof. Tyndall on the nature and value of Mayer's researches, in which they were so fully detailed that now, on the occasion of the death of the man whose

labours have won for him an undying renown, we need only briefly remind our readers of the chief events in his scientific career without entering into or attempting to renew a painful controversy of which it may be said that the truth lay neither wholly with one side nor the other.

Julius Robert Mayer was born at Heilbronn, November