On the existence of temporary depresssions in the solar climate of Siam.

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I. *Depressions caused by volcanic eruptions.*

In modern Meteorology under the denomination of solar climate we do not understand the theorical distribution of solar heat resulting only from the inclination of the sunrays in the zone in question, but the real distribution of the intensity and of the duration of sunshine, which results from direct measurements made with the actinometers and the sunshine recorders.

The results which were obtained with these instruments in Europe and in U. S. A. show that in the monthly values of the intensity of solar radiation, observed at the surface of the earth, there exist certain temporary and periodical depressions caused above all by volcanic eruptions.

During the period from 1883 to 1920 the following depressions have been observed.

a) Eruption of the small island of Krakatoa (near Java) in summer 1883.	Depressions in 1884, 1885 and 1886 in the values of the intensity of solar radiation at the earth's surface.
b) Eruptions of Bandaisan in 1888, of Bogoslof in 1890 and of Awoe, on Great Sangir in 1892.	Intermittent depressions during the period 1888-1892 of exceptional volcanic activity.
c) Eruptions of Santa Maria (1902), of Mount Pelé-Martinique (1902) and Colima (1903).	Depressions of solar radiation intensities observed in 1902, 1903 and 1904.
d) Eruption of Katmai (Alaska) in June 1912.	Depressions in 1912 and 1913.

One has furthermore observed a certain actinometric depression in 1907, a very short one in the summer 1916 and one in 1920, the origins of which are not yet known. It is not excluded that they depend on the fluctuation of the solar activity and not alone on the exceptional opacity of the earth's atmosphere caused by the volcanic dust.

II. *Actinometric depressions observed in the different places and expecially in Poland.*

According to Professor H. H. Kimball, who has used the actinometric measurements made at Montpellier, Paris, Warsaw, Lausanne, Simla and Washington, we find the following variations in the values of the solar radiation intensity, which we present by way of departures from the average of the observed values at all stations during the period 1883-1913.

TABLE I.

Departures (in %) of the annual values of the intensity of solar radiation during the period 1883/1913. Average for 6 stations Montpellier, Paris, Warsaw, Lausanne, Simla and Washington.

Year	Departure	Year	Departure	Year	Departure
1883	+ 4 %	1894	+ 3 %	1905	+ 1 %
84	− 7 „	95	+ 4 „	06	+ 3 „
85	−10 „	96	+ 4 „	07	− 1 „
86	− 3 „	97	+ 4 „	08	0 „
87	+ 6 „	98	+ 5 „	09	+ 3 „
88	+ 2 „	99	+ 4 „	1910	+ 3 „
89	+ 1 „	1900	+ 2 „	11	+ 4 „
1890	− 3 „	01	+ 3 „	12	− 7 „
91	− 4 „	02	0 „	1913	− 6 „
92	0 „	03	−11 „		
1893	+ 5 „	1904	− 3 „		

We see here the influence of all four volcanic eruptions of which we have spoken above.

For the period 1883/1892, solely based in the Table 1 upon the measurements of the intensity of solar radiation made at Montpellier (France), we add the corresponding values obtained with the actinometer Hershell-Arago at the observatory of Zi-Ka-Wei near Shanghai (China) and compiled by P. Stanislas Chevalier S. J. We give the departures of the annual values, calculated from the average for the period 1875/1892.

TABLE II.

Intensity of solar radiation at Zi-Ka-Wei (China), Departures of annual values from the average 1875/1892.

Year	Departure	Year	Departure	Year	Departure
1875	+ 2 %	1881	− 2 %	1887	+ 4 %
76	+ 5 „	82	− 4 „	88	− 4 „
77	+ 6 „	83	− 5 „	89	−12 „
78	+ 3 „	84	− 3 „	90	− 3 „
79	+11 „	85	− 3 „	91	− 1 „
1880	+ 2 „	1886	+ 3 „	1892	+ 1 „

We can see here very distinctly the influence of the eruption of Krakatoa and furthermore the decreased value during the period of exceptional volcanic activity in the years 1888, 1889 and 1890.

In order to complete the data in the Table I by those of the more recent years, we add the values obtained in Warsaw during the last years,

TABLE III.

Intensity of solar radiation at Warsaw (Poland). Departures of annual values from the average 1901/1918.

Year	Departure	Year	Departure	Year	Departure
1901	+ 4 %	1907	+ 2 %	1912	− 6 %
02	− 1 „	08	0 „	13	− 3 „
03	−13 „	09	+ 2 „	14	− 2 „
04	− 3 „	10	+ 1 „	15	− 1 „
05	+ 3 „	1911	+ 7 „	16	− 2 „
1906	+ 4 „			17	+ 1 „
				1918	+ 3 „

From the successive months of the period 1901/1918 we obtain the following departures.

TABLE IV.

Monthly maxima of the intensity of solar radiation at Warsaw, Poland. Departures (in %) from the respective monthly means during the period 1901/1918.

	Months											
	J	F	M	A	M	J	J	A	S	O	N	D
1901	-1	13	-4	6	5	3	3	9	2	4	5	14
02	0	8	6	2	-9	-5	7	5	8	-2	-13	-16
03	-23	-19	-15	-17	-21	-3	-7	-14	-11	-7	.	.
04	-21	-13	3	-2	6	-8	4	1	0	1	-5	-9
05	1	3	-1	2	8	5	5	3	7	2	-6	1
06	8	-6	3	4	4	4	2	-3	-1	9	23	16
07	-1	4	0	1	1	-3	-2	4	1	8	13	-3
08	9	-15	-7	-4	3	2	3	5	7	2	2	-4
09	0	-1	2	-3	5	1	.	3	0	-4	.	4
1910	5	2	5	-1	1	0	.	-2	1	2	.	-1
1911	.	6	12	5	8	7	9	5	7	11	13	.
12	37	17	-1	10	-4	3	-16	-14	-26	-27	-24	-16
13	-14	-1	-5	-2	-1	-3	-3	-1	4	1	-12	-4
14	-22	-4	-7	-1	-2	2	2	2	-4	-2	1	-3
15	-17	-6	3	3	1	4	-5	2	1	7	-6	-1
16	8	1	0	1	-1	-3	-5	-10	1	-5	-6	-2
17	14	5	-3	3	5	-4	4	4	1	-1	0	1
1918	14	5	6	-5	-4	3	3	2	1	1	11	5

Note. During the months for which the departures are not indicated, the sky has not been sufficiently clear at Warsaw and therefore no actinometric measurements have been made.

We note that the monthly maxima of the intensity of solar radiation at Warsaw (obtained with the electric pyrheliometer of Angström and the bimetallic actinometer of Michelson) have been uniformly reduced to the same value of air-mass and to the tension of vapour characteristic for each month.

The values in gram-calories per minute and 1 cm_2 of the surface normally exposed, have furthermore been reduced to the mean distance of the earth from the sun.

Further details may be found in the following publications of the author of the present paper:

a) Sur la marche annuelle de l'intensité du rayonnement solaire à Varsovie (8°, pp. 202, Montpellier et Varsovie, 1906).

b) On the depression in the value of the total intensity of the solar radiation in 1903, according to measurements made at the Central Station of the Polish Meteorological Service at Warsaw. (Monthly Weather Review, April 1907, Washington).

c) Valeurs pyrhéliométriques et les sommes d'insolation à Varsovie (Warsaw, 1914. Polish text with a French résumé)

In the Table IV one is immediately struck by the very great negative departures in 1903 and in 1912; we see there that the months with the particularly decreased values group themselves in a systematic manner from November 1902 to February 1907 and from July 1912 till January 1913.

Although in some other months the solar radiation intensity was decreased at Warsaw, these months have had altogether isolated and local character. This especially applies to the winter months in Poland, where the clear days are rare. After the marked depression of 1912 we observe at Warsaw a short depression in the summer 1916, which has also been found at Florence (Italy), at Canary Islands and at some other places.

III. *Depressions in the monthly values of solar radiation temperatures in Bangkok.*

After the general remarks, made in the foregoing paragraphs, we now arrive at our principal task to inquire whether and how the great volcanic eruptions manifest themselves in Siam and especially in Bangkok as the only place in this country, where the meteorological observations have been made during a longer period.

Unfortunately the capital of Siam does not possess a meteorological observatory; therefore neither actinometrical measurements nor observations of sunshine-duration have been made in Bangkok.

A superficial examination of the monthly means and maxima of the air-temperatures in Bangkok shows immediately a period of exceptional low values from June 1903 up to January 1904, corresponding—with a well understood delay—with the eruption of Martinique.

But instead of consulting still closer the means of air-temperature in shadow, which represent a very complicated and indirect function of the solar radiation and of the atmospheric transmissibility, we will use the "solar radiation" temperatures, observed at Bangkok with the special thermometers directly exposed to the sun. In modern meteorological equipment these "solar radiation" thermometers are hardly any more in use on account of their various sources of errors. But before exact measurements of the intensity of solar radiation by means of actinometers will be introduced in Bangkok, we are obliged to utilise the values observed with the solar radiation thermometers directly exposed to the sun. If we can arrive at a good result with these defectuous instruments, it will prove that the influence of volcanic eruptions manifest itself—on account of its mightiness—even under most difficult conditions.

This said we give now two tables (Va and Vb), one calculated from the data published by Dr. Campbell Highet (Vol. IX of "Journal of the Siam Society"), and the other from the "Statistical Year-Book of the Kingdom of Siam" (1922).

TABLE V (a, b)

Solar radiation temperatures in Bangkok. Departures (°F) of the monthly means from the averages of ten years.

Va. Departures (°F) from the monthly averages: 1902/1911.

	Months											
	J	F	M	A	M	J	J	A	S	O	N	D
1902	2	−2	−1	−5	−2	−1	1	−4	6	0	0	1
03	1	−3	−3	−4	−1	−12	−6	−10	−11	−10	−12	−12
04	−10	−6	1	0	3	2	−2	2	4	6	2	0
05	5	4	1	2	−2	1	3	4	−2	−7	−3	6
06	1	4	0	2	−6	−2	−5	−3	−5	−4	−6	−2
07	−2	−5	−6	−2	−6	−7	−10	−10	−8	−7	−1	−8
08	−1	−2	−2	−6	−5	0	0	−5	−7	−8	−8	−1
09	−2	−4	−2	0	1	8	6	8	7	12	6	6
10	5	8	5	7	6	5	7	10	3	7	7	4
1911	5	4	7	8	7	4	6	10	9	10	12	10

V b. Departures (°F) from the monthly averages: 1912/1920.

1912	2	3	1	1	2	4	5	2	4	2	-2	2
13	-1	-2	0	1	-5	4	3	-2	4	3	-1	1
14	-2	1	-2	1	5	2	-3	-2	1	1	4	3
15	-1	-1	0	-1	0	3	3	-1	1	-4	-2	-7
16	2	-2	-1	-1	-1	-4	-11	2	-2	0	-4	-2
17	-2	0	-4	-1	2	0	3	-1	-13	-12	-13	-4
18	-5	-3	-1	-1	-2	2	7	1	5	5	5	3
19	0	1	4	-1	-1	-2	4	2	3	6	1	2
1920	-2	2	1	0	4	-9	-16	-10	-10	-7	-2	-9

From the Table V (*a* and *b*) the following conclusions can be derived.

a) The influence of the eruption of Martinique (West Indies) is clearly to be seen at Bangkok, where the depression in the course of solar radiation temperatures especially manifests itself from June 1903 to February 1904 inclusive. We add that at Warsaw the corresponding depression has also been observed until February 1904.

b) The influence of eruption of Katmai (Alaska) in June 1912 has been much less felt in Bangkok, than the eruption of Martinique. We nevertheless find the solar temperatures in Bangkok systematically decreased in the first months of 1913.

c) The depressions of 1917 and of 1907, which have been found in some places and were only slightly visible at Warsaw, are however very much pronounced in Bangkok. As to the depression in 1920, so marked in the monthly values of solar radiation temperatures in Bangkok, it has also been found in North-America by Mr. Abbot.

IV. Depressions in Bangkok compared with those of Singapore and Batavia.

For better control of the aforementioned data of Siam, let us now examine, in what degree the variations of the solar temperatures, observed under the same conditions in Singapore, coincide with those of Bangkok. For this purpose we extract from the annual meteorological reports in Straits Settlements the following values.

TABLE VI.

Solar radiation temperatures at Singapore (Kampong Kerbau Hospital). Departures (°F) of the monthly means from the average 1902/1916.

	Months											
	J	F	M	A	M	J	J	A	S	O	N	D
1902	-13	-2	-7	-4	-2	-2	-4	-3	-4	-8	-4	-7
03	-4	-9	-5	1	-2	-6	-9	-11	-6	-8	-13	-4
04	-16	-5	-2	-4	-2	-3	.	-5	-3	-3	-3	-5
05	2	-8	-1	-2	-7	-3	-2	-4	-4	-4	-10	1
06	1	-5	-4	-2	-4	-8	-4	0	.	-3	1	-8
07	11	7	1	8	3	5	3	1	2	6	0	0
08	13	3	7	9	3	3	5	2	4	7	3	12
09	6	0	9	4	9	5	9	9	7	6	5	7
1910	7	-9	2	5	-1	1	4	-4	0	3	2	6
1911	-1	5	3	-14	0	5	3	2	-5	-2	-6	-12
12	-5	-2	6	-14	-12	-1	-1	-1	1	-2	-1	2
13	1	2	-16	-2	-1	-1	-1	-1	0	1	8	2
14	-7	7	2	4	7	-2	2	7	4	1	8	4
15	0	8	6	6	6	7	2	6	4	0	5	-1
1916	5	7	1	5	1	-1	-5	2	4	5	4	3

It results from the Table VI that the depression of 1903 exists in Singapore just as well as in Bangkok. The depression of 1912/1913 is in both places much less pronounced. The decrease in the summer 1916 is very slight, but nevertheless it exists in Singapore as well as in Bangkok.

As to the decrease of 1907 which has been so pronounced in Bangkok in July and August of this year, we find in the curve of Singapore during these months only an inflection in relation to the values observed in the first six months of 1907 and 1908.

Analogical conclusions are also to be obtained from the observations of maxima temperatures (black bulb in vacuum) in the sun, made at the meteorological station in Penang (Lat. 5° 34' N, Long. 100° 20' E. W., H = 5m).

In order to compare the values obtained in Siam and in the Malay Peninsula—by means of thermometers directly exposed to the sun—with a long series of observations made under more scientific conditions in another equatorial place, we will now regard the different meteorological data published by the Meteorological Observatory at Batavia (Java).

For the period of 1880/1915, embracing all the principal eruptions beginning from Krakatoa, we obtain the following table for Batavia, which on the one hand gives the departures from the annual mean of the cloudiness and of the relative humidity and on the other hand the direct observed values for the amounts of rainfall and for the numbers of rain days during three months and a whole year.

The departures for Batavia are calculated in % in relation to the corresponding averages for 36 years 1880/1915 viz.: 60% as the mean annual cloudiness of the sky and 83% as the annual average of the relative humidity of the air.—The average numbers of rain-days during three months: July, August and September and for the whole year, and also the amount of rainfall in millimeters during three months above mentioned are given in the Table VII.

TABLE VII.

Annual means of the cloudiness and of the relative humidity, and totals of rainfall and of raindays in Batavia. Departures (in %) from the average for the period 1880/1895.

	DEPARTURES		OBSERVED VALUES			
	Cloudiness of the sky	Relative Humidity	July, August, September		All months	
Average	60%	83%	20 Rain-days	177 millim.	160 Rain-days	
1880	0	1	38	420	213	
81	−5	−1	13	104	167	
82	3	1	34	303	184	
83	−3	−2	9	29	134	} Krakatoa
84	−2	−1	13	123	164	
85	−3	−2	3	22	139	
86	4	0	16	90	158	
87	3	0	23	264	148	
88	−5	−2	10	32	138	} Bandaisan
89	3	0	19	165	151	
1890	3	0	32	279	160	
1891	−5	−4	10	102	110	} Bogoslof
92	4	0	27	249	161	
93	7	1	24	223	180	
94	2	−1	9	64	158	
95	−5	0	19	245	162	
96	−13	−3	7	49	131	} Origin unknown
97	−6	−2	13	102	131	
98	−2	−1	13	164	150	
99	−1	0	27	292	181	
1900	2	1	21	139	175	
1901	−2	0	21	90	163	
02	−10	−3	7	12	135	} Martinique
03	−3	0	12	204	160	
04	3	1	31	322	190	
05	−2	5	13	115	143	
06	5	4	32	351	174	
07	5	3	34	310	193	
08	8	1	33	237	178	
09	12	2	26	211	181	
1910	12	1	31	250	184	
1911	6	−1	24	148	167	
12	−4	−1	27	366	172	} Alaska
13	−4	−1	22	67	183	
14	−9	−2	2	5	146	
15	1	0	20	227	194	

We see in the Table VII that all volcanic eruptions of which we have spoken before, have left well visible and important traces in the course of meteorological elements in Batavia.

The eruption of the Krakatoa in 1883 as well as the eruption of Martinique in 1902 and those of Alasca in 1912, have produced a diminution in the cloudiness and in the humidity, and at the same time considerable deficits in the amounts of rainfall and in the number of raindays. In Batavia we do not observe the decrease of 1907, which is found at Bangkok, but we see in return a depression in 1896 having probably a local character only.

In every case all the examples which we have given, authorize us to the conclusion that the volcanic eruptions produce everywhere periods of exceptional opacity of the earth's atmosphere.

These periods, having a mondial character, can be found not only by the direct measurements of the intensity of solar radiation at the earth's surface, made with the actinometers, but can also be proved (the example of Bangkok shows this amply) by the otherwise very critisable observations made with the thermometers directly exposed to the sun. The example of Batavia shows furthermore that the influence of these depressions also affects the rainfall, which is of great practical importance in a tropical country as Siam.

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