SECTION I.—AEROLOGY.

551.521.1(75.3)"1914.10/11/12

SOLAR RADIATION INTENSITIES AT WASHINGTON, D. C., DURING OCTOBER, NOVEMBER, AND DECEMBER, 1914.

By HERBERT H. KIMBALL, Professor of Meteorology.

[Dated Weather Bureau, Washington, D. C., Jan. 12, 1915.]

As stated in this REVIEW for September, 1914 (p. 520), most of the solar radiation apparatus that had been in use at Mount Weather, Va., was transferred at the end of September to rooms in the American University, Washington, D. C., where radiation investigations are now being conducted in cooperation with that university. Advantage was taken of the unavoidable interruption in the record to restandardize the Marvin pyrheliometer, and during October and November all radiation measurements were made with Smithsonian silver-block pyrheliometer No. 1.

The American University (lat. = 38° 56′ N., long. = 77° 4′ W.) is on a plateau about 5½ miles northwest of the United States Capitol, 4 miles northwest of the White House, and 1½ miles northwest of the United States Naval Observatory. There are only a few scattered residences within a mile of it in any direction. Beyond this limit is open country to the west and south, much of it woodland, scattered suburban villages to the north, and the residence section of Washington to the east and southeast. There are no manufacturing establishments within about 3 miles, and the only steam railroad within a radius of about 5 miles is a spur over which freight cars are hauled at infrequent intervals. The university is therefore practically free from city influences, except with east and southeast winds, when the sky is apt to be overcast with clouds.

The Marvin pyrheliometer is exposed from windows on the second floor of the College of History, 26 feet above the ground, and 418 feet (127.4 m.) above sea level. A window facing southeast affords continuous exposure to the sun from sunrise to noon, and a window facing southwest affords continuous exposure from noon until sunset. The pyrheliometer is exposed on a shelf just outside the window, but is protected from high winds by the wide window jambs.

A Callendar pyrheliometer is exposed on the top of a ventilating flue near the center of the building, 59 feet above the ground, and 451 feet (137.5 m.) above sea level. A nocturnal radiation instrument is exposed on the top of the same flue, and a Pickering polarimeter exposed from a platform on the roof, is at about the same height.

In Table 1 are summarized the solar radiation measurements made during the months of October, November, and December, 1914. Those for October 1 and 2 were made from the roof of the central office of the Weather Bureau, 3 miles southeast of the university, and at an elevation of about 130 feet (39.6 m.) above sea level. The first readings at the university were obtained on October 21, and all subsequent readings have been made at that place.

For details relative to the number and frequency of radiation measurements and the method of interpolating readings to the air masses given in the headings of the table the reader is referred to pages 138 and 310 of the current volume of the REVIEW.

TABLE 1.—*Solar radiation intensities at Washington, D. C., during October, November, and December, 1914.*

[Gram-calories per minute per square centimeter of normal surface.]

Date.	Air masses.									
	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
1914.	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*
A. M.										
[1] Oct. 2	1.12	1.05								
28	1.39									
31	1.31									
Means	1.27	(1.05)								
P. M.										
[1] Oct. 1	1.34	1.25	1.17	1.09	1.02	0.97				
[2] 21	1.18	1.07								
30	1.39									
31		1.17	1.09	1.01	0.94	0.87	0.81	0.76		
Means	1.30	1.19	(1.13)	(1.05)	(0.98)	(0.92)	(0.81)	(0.76)		
A. M.										
Nov. 2		1.08	0.99	0.91						
3		1.13	1.05		0.90	0.84	0.80			
4		1.03	0.93							
7		0.70	0.58							
10		1.37	1.29	1.20	1.13	1.08	1.02	0.97	0.92	0.87
12		1.14	1.05	0.94	0.83	0.77	0.72	0.67	0.60	
17			1.30	1.23	1.16	1.11	1.04	0.96	0.92	0.91
18		1.11								
20				0.60						
21		1.26	1.16			0.97	0.91	0.84	0.80	
23		1.29	1.11							
24		1.16	1.13	1.10						
Means		1.13	1.06	1.00	1.01	0.95	0.90	0.86	0.81	(0.89)
P. M.										
Nov. 2		1.17								
4		0.92	0.86	0.76	0.64	0.58	0.52			
5		1.16	1.04	0.92	0.81	0.71	0.62	0.55		
6		1.20	0.91	0.81	0.74	0.71	0.70	0.57		
7		0.80	0.64	0.45						
9		1.33	1.22							
10		1.34	1.20							
13		1.08	0.87	0.79						
16		1.34	1.26	1.14	1.03	0.96	0.90	0.85	0.81	0.78
23		1.29	1.14	1.03	0.97	0.92	0.87	0.81	0.74	0.67
24		1.27	1.19	1.05	0.94					
Means		1.17	1.03	0.87	0.86	0.78	0.72	0.70	(0.78)	(0.72)
A. M.										
Dec. 12						0.63	0.57	0.52	0.47	
15		1.34	1.30	1.17	1.11	1.04	0.97	0.91	0.85	
16		1.34	1.27	1.19	1.11	1.04	0.98	0.92	0.86	0.82
17		1.24	1.12	1.03	0.96	0.88	0.83	0.76	0.71	0.67
18		1.07	0.93	0.81	0.72	0.66	0.61	0.56	0.52	0.48
26		1.51	1.42							
Means		1.30	1.21	1.05	0.98	0.85	0.79	0.73	0.68	0.66
P. M.										
Dec. 14			1.02	0.90	0.81	0.76	0.71	0.67	0.65	
15			1.26	1.18	1.10	1.02	0.95	0.90	0.85	0.82
16			1.24	1.16	1.09	1.04	0.99	0.94	0.89	0.85
17			1.14	1.05	0.95	0.85	0.78	0.73	0.69	0.65
18			1.00	0.93	0.83	0.74	0.67	0.63	0.58	
21			1.23							
23			1.19							
26			1.41	1.32	1.24	1.16	1.09	1.04	1.00	0.97
27			1.22	1.14			0.94	0.89	0.84	0.80
Means			1.19	1.10	1.00	0.93	0.88	0.83	0.79	0.82

[1] Observations taken at central office.
[2] First observation taken at the American University.

In Table 1 the mean values corresponding to air-mass 2 for December are higher, and for November they are lower, than the corresponding normals published in the Bulletin of the Mount Weather Observatory, v. 5, p. 182, table 3. These normals are based on observations made at the Weather Bureau, Washington, between 1905 and 1910.

The maximum radiation intensities for air-mass 2 in November and December exceed the corresponding maxima obtained at Mount Weather in 1913. Table 2 shows that the readings obtained on December 26 exceed any hitherto obtained in the vicinity of Washington with the sun at a zenith distance of 60° or more. The table shows that they are not so high as readings that have been obtained at Madison, Wis., at an elevation of 974 feet (296.9 m.) above sea level, or intermediate to the elevations of Mount Weather and the American University. Some observations on the increase of insolation with elevation, published in the Bulletin of the Mount Weather Observatory, v. 6, p. 107, indicate that while in hazy weather, and especially in the warm part of the year when the atmosphere contains considerable moisture, differences of from 500 to 1,000 feet in elevation may cause several per cent difference in radiation intensities, with an atmosphere comparatively free from dust and moisture the effect of such differences in elevation is hardly appreciable.

TABLE 2.—*Maximum solar radiation intensities.*

[Gram-calories per minute per square centimeter of normal surface.]

Station.	Air masses.										
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
	Gr.-cal.	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*
Mount Weather, Va.	1.53	1.48	1.43	1.34	1.27	1.20	1.15	1.09	1.04	1.00	0.96
Washington, D. C.[1]	1.53	1.49	1.41	1.32	1.23	1.15	1.10	1.04	0.96	.....	.....
Washington, D. C.[2]	.....	.....	1.51	1.42	1.32	1.24	1.16	1.09	1.04	1.00	0.97
Madison, Wis.	1.58	1.61	1.57	1.58	1.47	1.36	1.28	1.18	1.17	1.12	.....

[1] Highest observed at Washington, D. C., previous to Dec. 26, 1914.
[2] Readings on Dec. 26, 1914.

The meteorological conditions on December 26 were conducive to an atmosphere unusually free from dust and water vapor. Cold northwest winds out of an area of high pressure prevailed, and the region from which they came, as well as that immediately surrounding Washington, was covered with snow that fell on the 24th. At 8 a. m. of the 26th the temperature at the Weather Bureau, Washington, was 8°F., or −13°C., and the vapor pressure was 1.19 mm. At 8:30 p. m. the temperature at the University was −11.5°C., and the vapor pressure was 1.10 mm. According to Abbot[1] the absorption of solar radiation by the vapor content of the atmosphere indicated by this vapor pressure, with the sun at zenith distance 60°, would not exceed 6 per cent.

In Table 3 are given the readings on which the tabulated values for the A. M. of December 26 are based. In Table 4 are given comparative readings of Marvin pyrheliometer No. 3 and Smithsonian silver-disk pyrheliometer No. 1. These were made on January 7, 1915, the first favorable day for such readings after December 26. It will be noted that the probable error in the mean of series of readings in either Table 3 or 4 is very small, and that the two pyrheliometers are in practical accord.

[1] Annals of the Astrophysical Observatory of the Smithsonian Institution, v. 2, p. 130.

TABLE 3.—*Radiation measurements made before noon of Dec. 26, 1914.*

Sun's hour angle from noon.	Sun's altitude.	Air mass.	Radiation (Q.).
H. m.	° ′		*Gr.-cal.*
2 04	21 17	2.74	1.386
2 03	21 22	2.72	1.385
2 02	21 28	2.71	1.380
2 01	21 34	2.70	1.388
2 00	21 40	2.69	1.383
1 59	21 46	2.68	1.385
0 23	27 29	2.16	1.480
0 22	27 30	2.16	1.474
0 21	27 31	2.16	1.478
0 20	27 32	2.16	1.480
0 19	27 33	2.16	1.481
0 18	27 34	2.16	1.475
0 17	27 35	2.15	1.478
0 16	27 36	2.15	1.489
0 15	27 37	2.15	1.494
0 14	27 38	2.15	1.486
0 13	27 39	2.15	1.478
0 12	27 39	2.15	1.481
0 11	27 40	2.15	1.486
0 10	27 41	2.14	1.480

TABLE 4.—*Comparative readings of Smithsonian pyrheliometer No. 1 and Marvin No. 3.*

Sun's hour angle from noon.	Sun's altitude.	Air mass.	Radiation.	
			Marvin No. 3.	Smithsonian No. 1.
H. m.	° ′		*Gr.-cal.*	*Gr.-cal.*
0 38	28 01	2.12	1.331	.....
0 37	28 03	2.12	1.332	.....
0 36	28 05	2.12	1.332	1.327
0 35	28 07	2.12	1.334	.....
0 34	28 09	2.12	1.338	1.345
0 33	28 11	2.11	1.336	.....
0 32	28 13	2.11	1.338	1.321
0 31	28 14	2.11	1.339	.....
0 30	28 16	2.11	1.345	1.342
0 29	28 18	2.10	1.354	.....
0 28	28 19	2.10	1.359	1.346
0 27	28 21	2.10	1.361	.....
0 26	28 22	2.10	1.356	1.344
0 25	28 24	2.10	1.356	.....
0 24	28 25	2.10	1.361	1.326
0 23	28 26	2.10	1.359	.....
0 22	28 27	2.10	1.354	1.349
0 21	28 28	2.09	1.348	.....
0 20	28 29	2.09	1.345	1.348
0 19	28 30	2.09	1.346	.....
0 18	28 31	2.09	1.348	1.350
0 17	28 32	2.09	1.348	.....
0 16	28 33	2.09	1.344	1.346
0 15	28 34	2.08	1.341	.....
Means	.....	.....	1.346	1.340

Skylight polarization measured at a point 90° from the sun and in the same vertical circle, with the sun at zenith distance 60°, averaged 65 per cent in November and 62 per cent in December, excluding from the latter month all measurements made after the snowfall of the 24th. The maximum for November was 72 per cent and for December 66 per cent. Comparing these with the averages and departures published in the Bulletin of the Mount Weather Observatory, Volume 3, page 114, Table 16, it will be seen that they are 6 per cent and 3 per cent, respectively, above the average. The November maximum is as high as any previously measured in Washington.

The above observations, taken in connection with the readings obtained at Mount Weather, Va., in September, 1914, and published on page 520 of the current volume of this REVIEW, indicate unusually clear skies in the vicinity of Washington during the latter part of 1914.