TABLE 2.—*Vapor pressures at pyrheliometric stations on days when solar radiation intensities were measured.*

Washington, D. C.			Madison, Wis.			Lincoln, Nebr.			Santa Fe, N. Mex.		
Dates.	A. M.	P. M.	Dates.	A. M.	P. M.	Dates.	A. M.	P. M.	Dates.	A. M.	P. M.
1918.	*mm.*	*mm.*	1918.	*mm.*	*mm.*	1918.	*mm.*	*mm.*	1918.	*mm.*	*mm.*
Feb. 4	1.12	0.64	Feb. 6	2.16	2.74	Feb. 3	1.32	1.52	Feb. 1	1.32	1.96
11	4.17	4.57	12	4.17	3.45	6	3.99	5.16	9	2.16	2.06
14	3.81	7.29	15	0.97	1.07	16	0.86	1.24	12	2.74	2.74
15	7.57	3.81	22	0.97	1.88	20	0.48	0.74	13	2.74	2.16
18	1.78	2.87	23	2.62	4.75	22	1.68	3.00	14	2.26	2.06
21	1.24	1.19	26	1.68	2.87	23	3.15	5.79	15	2.74	2.06
23	1.88	2.87	....	.....	.....	....	.....	.....	16	1.96	2.06
25	6.02	7.57	....	.....	.....	....	.....	.....	19	2.16	1.52
26	2.36	2.74	....	.....	.....	....	.....	.....	23	4.75	3.81
27	3.63	4.17	....	.....	.....	....	.....	.....	....	.....	.....

TABLE 3.—*Daily totals and departures of solar and sky radiation during February, 1918.*

[Gram-calories per square centimeter of horizontal surface.]

Day of month.	Daily totals.			Departures from normal.			Excess or deficiency since first of month.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
1918.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Feb. 1	122	317	358	− 84	112	95	−84	112	95
2	156	257	306	− 52	49	40	−136	161	135
3	98	315	337	−113	105	68	−249	266	203
4	320	338	306	107	125	34	−142	391	237
5	347	137	182	132	− 79	− 93	− 10	312	144
6	240	297	320	22	78	42	12	390	186
7	281	176	272	59	− 47	− 10	71	343	176
8	252	30	34	27	−196	−251	98	147	−75
9	63	307	376	−165	78	87	− 67	225	12
10	264	274	386	33	41	94	− 34	266	106
11	313	269	196	79	33	−100	45	299	6
12	226	284	286	− 12	45	− 13	33	344	−7
13	275	257	216	34	14	− 87	67	358	− 94
14	205	113	147	− 39	−133	−159	28	225	−253
15	334	359	75	87	110	−234	115	335	−487
16	87	271	403	−164	18	91	− 49	353	−396
17	369	363	389	115	107	74	66	460	−322
18	371	167	271	114	− 92	− 47	180	368	−369
19	67	32	226	−193	−231	− 94	− 13	137	−463
20	282	393	437	18	127	114	5	264	−349
Decade departure							+ 39	− 2	−455
21	399	267	383	132	− 2	57	137	262	−292
22	129	388	375	−141	115	46	− 4	377	−246
23	394	343	363	120	67	31	116	444	−215
24	233	352	294	− 44	73	− 41	72	517	−256
25	184	43	287	− 96	−239	− 51	− 24	278	−307
26	448	321	330	164	35	− 11	140	313	−318
27	406	311	90	118	21	−254	258	334	−572
28	333	164	368	41	−129	21	299	205	−551
Decade departure							+294	− 59	−202
Excess or deficiency since first of year: cal.							+137	+869	−755
Excess or deficiency since first of year: Per cent							+1.1	+7.1	−5.0

TABLE 4.—*Solar radiation intensities for zenithal sun and approximate values of the solar constant.*

Station.	Date.	Radiation intensity.		Solar constant.
		m=1	m=0	
	1918.	*cal.*	*cal.*	*cal.*
Lincoln, Nebr	Feb. 3	1.54	1.71	....
Lincoln, Nebr	Feb. 16	1.52	1.73	....
Santa Fe, N. Mex	Feb. 1	1.62	1.84	1.92
Santa Fe, N. Mex	Feb. 9	1.56	1.78	1.87

NOCTURNAL RADIATION MEASUREMENTS.

By Prof. HERBERT H. KIMBALL.

[Dated: Washington, Feb. 19, 1918.]

APPARATUS.

In making the nocturnal radiation measurements here summarized a modification of the Ångström electrical compensation instrument has been employed.[1] As is well known, the radiating surface in this instrument consists of two thin blackened strips of manganin. The rate at which these strips lose heat by radiation is determined by measuring the electric current that must be passed through them in order to maintain temperature equilibrium between them and two other strips of manganin similar to these in every way except that their surfaces are bright. The bright strips are exposed beside the blackened strips, and under exactly the same conditions.

The pyrgeometer.—Figure 1 shows the bright strips (*W, W*) and black strips (*B, B*) mounted on a hard rubber frame in the end of a nickel-plated tube. In order to determine when the four strips are in temperature equilibrium thermo-electric junctions (*j, j*) are provided at their backs, but electrically insulated from them. These junctions are connected in series in a circuit that also includes the coil of a delicate galvanometer, *G*. A slight temperature difference between the junctions back of the bright and the black strips, respectively, generates a current which, passing through the galvanometer coils, deflects them from their zero position. The blackened strips are then warmed by passing through them an electric current, which is adjusted to such strength that the galvanometer coils return to their zero position, indicating the establishment of the temperature equilibrium sought. Under these conditions the blackened strips are receiving the same amount of heat that is being lost by radiation, provided the bright strips are perfect reflectors and do not lose heat by radiation. Actually, however, the bright strips are imperfect reflectors and lose some heat by radiation. The electric heating current is therefore a measure of the difference in the radiating powers of the bright and the black strips. Such devices have been called pyrgeometers by A. Ångström (op. cit., p. 28).

The Weather Bureau has had four of these pyrgeometers constructed. Nos. 1, 2, and 3, had two blackened and two bright manganin strips, the bright strips being gold plated. Five silver-bismuth thermo-electric junctions are provided at the back of each strip, so that there are 10 warm and 10 cold junctions on each instrument. These junctions were made by Dr. W. W. Coblentz,[2] of the United States Bureau of Standards, who also prepared the bright and black strips and mounted them on sup-

[1] *Ångström, Knut.* Über die Anwendung der elektrischen Kompensationsmethode zur Bestimmung der nächtlichen Ausstrahlung. Nova acta, Regiæ societatis scientiarum Upsaliensis, Upsala, 1905, Ser. IV, vol. 1. N. 2.

[2] *Coblentz, W. W.* Instruments and methods used in radiometry. Bull., U. S. Bureau of Standards, 1913, 9: 7–63.

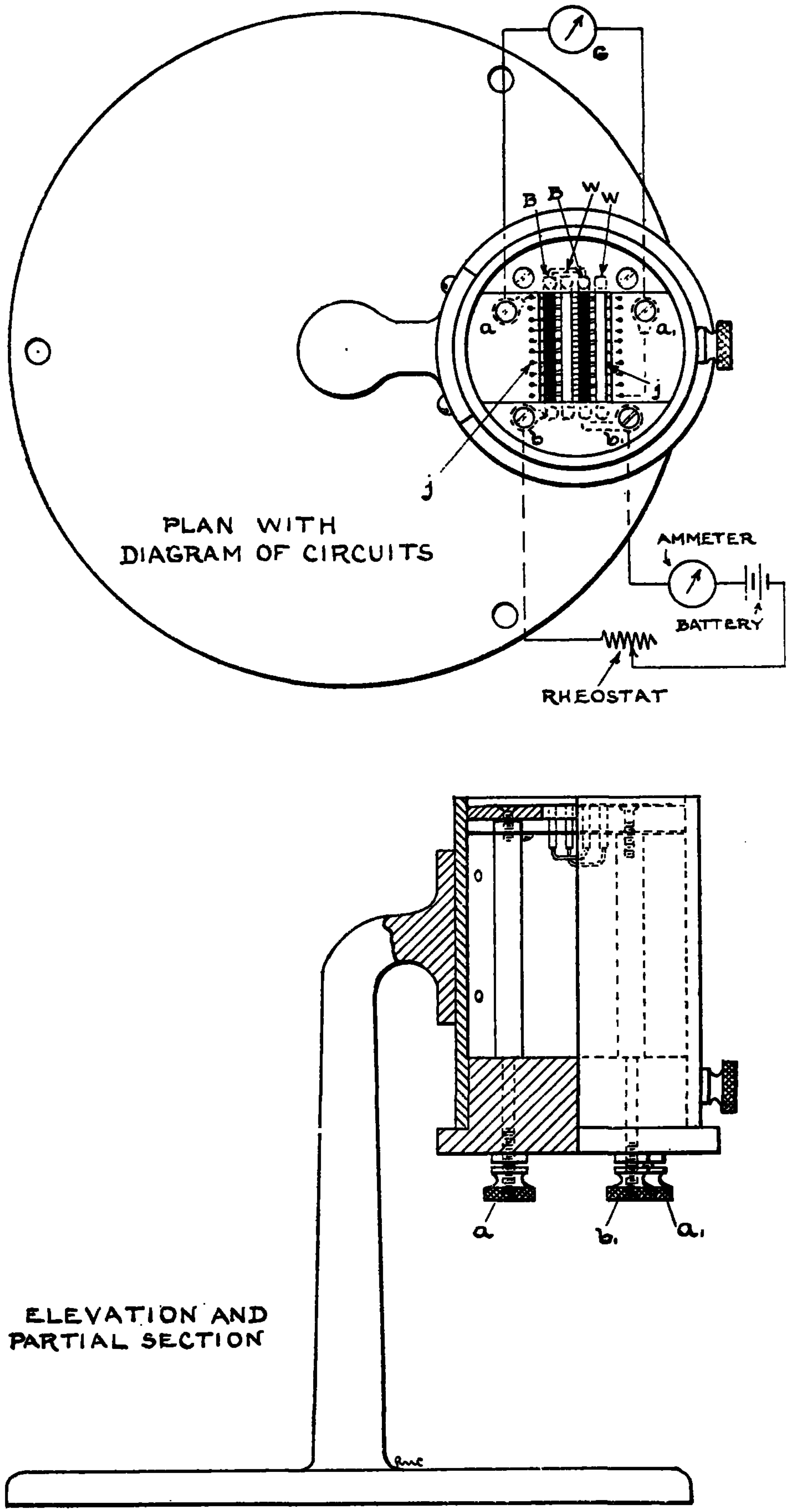

FIGURE 1.—The pyrgeometer, with diagram of electric circuits.

ports made up in the Weather Bureau machine shop. These strips are about 0.03mm. thick, 2mm. wide, and 20mm. long. The resistance of each strip is about 0.15 ohm, and that of the thermopile is about 3.5 ohms.

Instrument No. 1 was constructed in 1914 and used in measurements at Mount Weather, Va., and later at the American University, Washington, D. C. During March 1915, one of the fine bismuth wires of the thermopile was broken,[1] and there was evidence that the gold-plated surfaces had been corroded by acid fumes from a drying mixture. These strips were therefore replaced by platinum strips, and the instrument was designated No. 1_{bis}.

STANDARDIZATION OF PYRGEOMETERS.

For determining the rate at which heat is exchanged by radiation between two black bodies we may make use of the Stefan-Boltsmann law

$$R = \sigma(T_1^4 - T_2^4), \qquad (1)$$

where T_1 and T_2 represent the absolute temperatures of the two bodies, and σ is the radiation constant for a black body. The value of σ is here assumed to be 5.7×10^{-12} watts per square centimeter, or 8.18×10^{-11} gram-calories per minute per square centimeter, a value $6\frac{1}{2}$ per cent greater than that employed by both K. and A. Ångström.[3] If we represent by i the amperage of the electric current required to maintain temperature equilibrium between the bright and black strips of the pyrgeometer we may also write

$$R = Ki^2 = \sigma(T_1^4 - T_2^4), \qquad (2)$$

in which K is a constant depending upon the dimensions

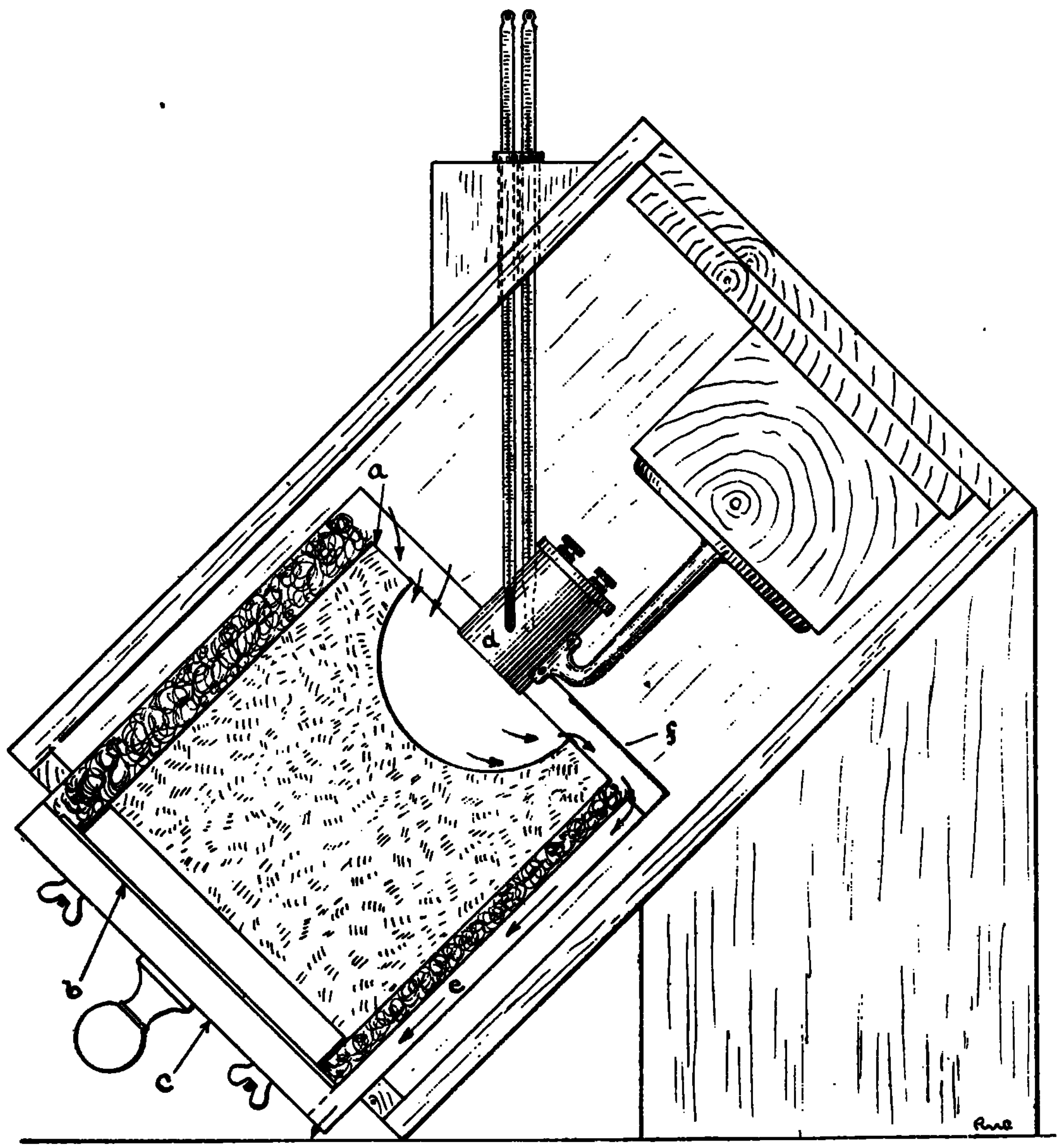

FIGURE 2.—Apparatus for standardizing pyrgeometers.

and the electrical resistance of the strips. Hence by measuring T_1, the temperature of the pyrgeometer, T_2, the temperature of that to which it is radiating, and i, the amperage of the heating current, we may determine K with the degree of accuracy to which σ is known.

Standardizing apparatus.—Figure 2 shows the character of the apparatus employed in standardizing the pyrgeometers. A copper can, *a*, is made up with a bottom that, viewed from the outside, contains a concave hemi-

[3] *Ångström, Anders.* A study of the radiation of the atmosphere. Smithsonian misc. coll., Washington, 1915, **65**, No. 3, p. 30.

spherical indentation, the surface of which is blackened by the smoke from burning camphor. The can is filled with a mixture of finely shaved ice and water, and the open end is closed by means of a rubber gasket, *b*, under a wooden cover, *c*, that is drawn down tight. The can is placed inside a cylinder of tin, and the annular space between is filled with hair. The blackened end of the can is inserted in a box, as shown in figure 2, which is tilted at an angle of about 45°. The pyrgeometer to be standardized, *d*, is then exposed to the blackened cup-like depression in the end of the can, with the strips just even with the edge of the cup. An electric fan is employed to force air into the box near the bottom. This not only equalizes air temperatures throughout the box, but it also facilitates the outward flow, by way of the passage *e*, provided through the annular space, of air cooled by contact with the blackened cup. The end of the cylinder inside the box is closed on its lower side by a segment of tin, as shown at *f*, figure 2, to prevent the flow of this cold air into the box.

Equation (2) is applicable for the determination of K only in case the blackened end of the cold copper can and the blackened manganin strips of the pyrgeometer are perfect radiators and the bright strips are perfect reflectors, so that their emission coefficient is zero. It has already been stated that this is not true of the black and bright strips, and the same must also be said of the blackened can.

Let n represent the coefficient of absorption of the blackened strips, m that of the bright strips, and p that of the blackened end of the can. Further, let us assume that none of the surfaces are selectively absorptive for radiation of the wave lengths to be measured. Equation (2) may then be written

$$Ki^2 = (n-m)p\sigma(T_1^4 - T_2^4), \tag{3}$$

from which

$$K' = \frac{K}{(n-m)p} = \sigma\frac{T_1^4 - T_2^4}{i^2}. \tag{4}$$

The last member of equation (3) applies to measurements of black-body radiation if p is given the value 1.0. But for such measurements, K', as determined by the above calibration method, is too large by the ratio $\frac{1.0}{p}$, or about $\frac{1.0}{0.98} = 1.02$.

Ångström [4] states that the value of m for gold-plated strips is about 3 per cent, and that because of this value the strips will remain at a temperature slightly below the air temperature. We wish to determine the rate at which a black body at air temperature loses heat by radiation to the atmosphere; therefore, in equation (3), T_1 should represent the temperature of the air surrounding the body. In the calibration measurements the temperature was determined by placing a mercurial thermometer on each side of the instrument. One thermometer was where it could radiate freely to the cold can, and the other was somewhat shielded from it by the instrument. A part of the time a resistance thermometer was placed inside the case of the instrument, and just back of the thermopile. Unfortunately, suitable terminals were not provided for this thermometer and it was found, after a time, that in transferring it from one instrument to another its resistance had been diminished, so that its temperature indications were too low.

[4] *Ångström, Anders.* Opus cit., p. 31.

During most of the tests a small screen was placed between the bulbs of the mercurial thermometers and the cold can.

TABLE 1.—*Comparisons of temperatures measured by a resistance thermometer inside the case of the pyrgeometer, and by mercurial thermometers on each side of the instrument.*

Date.	Thermometers.		
	Resistance.	Mercurial beside instrument.	Mercurial behind instrument.
1915.	°C.	°C.	°C.
Jan. 30 [a]	19.46	19.59	20.67
30 [a]	19.28	*20.29	20.63
30	19.08	*19.82	20.18
30 [a]	18.97	19.20	20.34
Feb. 19 [b]	[c] 21.78	†21.77	†22.09
19 [b]	[c] 20.94	21.38	21.46
Mar. 2 [b]	[c] 13.97	†14.63	†14.77
3 [b]	[c] 18.80	18.91	18.93
3 [b]	[c] 18.60	19.05	19.15

*Bulb of thermometer shielded from cold surface of can by a small plate of aluminum.

†Bulbs of both thermometers shielded from cold surface of can by sheet of blotting paper.

[a] Box thoroughly ventilated.

[b] Box slightly ventilated.

[c] Resistance thermometer covered with tinfoil.

Table 1 gives the most reliable synchronous readings between the three thermometers. From these and other readings it was found that a slight movement of air through the box was necessary, in order to prevent temperature gradients in the box. Furthermore, it was necessary to make sure that the air cooled by contact with the cup-like depression in the end of the can flowed outward by the passage provided for that purpose, and not into the box. Likewise, it was necessary to maintain nearly stationary temperature conditions in the box during a series of readings, as the temperature of the instrument lagged behind the temperature of the air. At Mount Weather this was easily accomplished, as the apparatus was set up in a constant temperature room; but at Washington it was difficult to maintain a sufficiently uniform temperature in the box. Care was necessary also to keep the dew-point in the box below 0° C, as otherwise condensation took place on the cold end of the can, and the heat thus liberated materially modified the rate of cooling of the blackened surface. At Mount Weather this also was accomplished without difficulty by forcing air through a drying tube before its entrance into the box. At Washington it has been practicable to make standardization tests on cold dry winter days only.

With the above conditions fulfilled the mercurial thermometer exposed to the cold blackened end of the can read about 0.2° C. higher than the resistance thermometer inside the case of the instrument, and the shielded mercurial thermometer read about half a degree higher. These temperature differences, under the conditions of the tests, caused differences of about 1 per cent and 3 per cent, respectively, in the measured rates of radiation. The latter is Ångström's estimate, referred to above, for the emission coefficient of the gold-plated strips. The temperature of the air about the instrument undergoing test, or T_1, has therefore been assumed to be that of the shielded thermometers, and the temperature of the blackened cup-like end of the ice-filled can, or T_2, has been assumed to be 0° C.

TABLE 2.—*Summary of standardizations of pyrgeometers.*

Number 1.			Number 1_{bis}.			Number 2.			Number 3.		
Date.	*T.*	*K'.*	Date.	*T.*	*K'.*	Date.	*T.*	*K'.*	Date.	*T.*	*K'.*
1914.			*1915.*			*1914.*			*1914.*		
May 8	288.2	9.09	Mar. 23	287.6	7.47	Mar. 2	292.7	7.50	Mar. 2	287.7	6.72
8	288.1	9.08	23	287.8	7.54	3	290.2	7.44	3	291.0	6.51
8	288.0	9.39	23	287.8	7.58						
14	288.9	8.95	23	288.2	7.24						
14	288.7	9.38	23	288.7	7.33						
14	288.6	9.57	23	289.5	7.45						
14	288.4	9.54	23	289.7	7.47						
14	288.4	9.54	23	289.7	7.47						
14	288.2	9.55									
14	288.1	9.55	*1916.*								
14	288.1	9.60	Feb. 4	287.9	7.24						
14	288.1	9.43	4	287.3	7.35						
22	289.2	8.80	4	287.2	7.52						
22	289.0	8.75									
22	288.9	8.84									
22	288.4	9.17									
22	288.4	9.21									
22	288.4	9.21									
Means		9.24			7.42			7.47			6.62
Corrected for *p*.		9.1	By comparative readings.		7.42			7.3			7.0
1915.											
Mar. 2	291.6	9.86	Corrected for *p*		7.3			7.2			6.9
2	290.5	9.92									
Mean		9.89									
Corrected for *p*.		9.7									

In Table 2 are summarized the standardization measurements on the different instruments. At the American University, in Washington, during March and April, 1915, and in North Carolina, during May, 1915, numerous comparisons were made between pyrgeometers Nos. 1_{bis}, 2, and 3. The ratios of the radiation measurements by these instruments, reduced to heat units by the use of the mean values of K' determined by standardization tests, are given in Table 3. From these ratios it appears that the value of K' for pyrgeometer No. 2 as thus determined is too high, and that determined for No. 3 is too low. The values of K' derived from these comparisons are also given in Table 2, and, finally, the adopted values, obtained by correcting the above for the error due to the fact that the value of p is about 0.98 instead of 1.0.

TABLE 3.—*Comparisons of pyrgeometers.*

Stations.	Ratios of radiation measurements.		
	$\frac{\text{No. 2}}{\text{No. } 1_{bis}}$	$\frac{\text{No. 3}}{\text{No. } 1_{bis}}$	$\frac{\text{No. 3}}{\text{No. 2}}$
Washington, D. C.	1.01	0.936	0.940
North Carolina	1.03	0.926	0.940

It seems probable that the high value of K' obtained for pyrgeometer No. 1 is due to the fact that the surfaces of the bright strips were corroded by fumes from a drying mixture before the tests were made at Mount Weather. The restandardization tests made in Washington in March, 1915, indicate that the corrosion had progressed in the meantime. The factor $K'=9.1$ was used in reducing all observations obtained at Mount Weather between May and September, 1914, however, and the factor $K=9.7$ in reducing the observations obtained at the American University in Washington between December, 1914, and March, 1915.

In August, 1917, Smithsonian pyranometer[5] No. 2 was compared with pyrgeometers Nos. 1 and 3. The former was greatly disturbed by wind currents, so that the results were quite inconclusive. The pyranometer sometimes read higher and sometimes lower than the pyrgeometers.

NOCTURNAL RADIATION MEASUREMENTS AT MOUNT WEATHER, VA., AND WASHINGTON, D. C.

In Table 4 are summarized the radiation measurements made at Mount Weather, Va., with pyrgeometer No. 1. The instrument was exposed on the capstone of the ventilating flue of the physical laboratory, and there was practically no obstruction between it and the sky in any direction down to the true horizon.[6] The elevation above sealevel was about 540 meters.

TABLE 4.—*Summary of nocturnal radiation measurements at Mount Weather, Va.*

[Gram-calories per minute per square centimeter.]

Date.	Time.	*R.*	*t.*	*e.*	Remarks.
1914.	*H. m.*	*cal.*	°*C.*	*mm.*	
May 14	10:37 p.	0.129	11.1	5.56	Stars shining; St.Cu.
14	11:02 p.	0.078	10.9	5.79	Cloudiness increasing.
18	8:30 p.	0.205	16.8	5.16	Light haze.
18	11:06 p.	0.202	16.2	4.95	Indications of Ci.
18	11:53 p.	0.202	15.9	4.57	
19	1:08 a.	0.205	15.9	4.37	
19	2:20 a.	0.205	15.6	4.57	
19	8:40 p.	0.208	18.7	4.95	Dense haze.
20	2:44 a.	0.197			
20	2:59 a.	0.194	16.7	4.95	
20	3:12 a.	0.193			
20	3:36 a.	0.192			
20	4:00 a.	0.193	16.7	5.16	
20	4:18 a.	0.192			
20	4:50 a.	0.186	16.3	4.85	
20	8:15 p.	0.190	23.6	5.16	Dense haze.
21	8:32 p.	0.183			Stars shining; some Ci.St.
21	8:52 p.	0.183	22.3	7.70	Do.
22	8:22 p.	0.152			10/10 St.Cu. at 8 p. m. obs.; cleared later
22	8:34 p.	0.153	20.8	7.87	
23	8:32 p.	0.176	18.1	4.17	6/10 Ci. at 8 p. m.
24	8:56 p.	0.147	17.8	6.76	4/10 Ci.St. at 8 p. m.
27	8:30 p.	0.069			7/10 A.Cu.
27	8:40 p.	0.091	25.6	11.81	3/10 A.Cu.
28	8:36 p.	0.110	24.4	14.60	5/10 St.Cu.
31	8:39 p.	0.173	20.0	8.48	2/10 A.St.; light smoke.
June 2	8:49 p.	0.219	18.3	4.75	Ci.St. clouds at sunset.
3	2:37 a.	0.191	17.8	4.37	Light haze.
3	3:04 a.	0.199	17.8	4.37	
3	3:29 a.	0.203	16.9	4.57	
3	3:58 a.	0.198	15.6	4.57	
3	4:11 a.	0.198			
3	4:28 a.	0.197	15.6	4.95	
3	4:50 a.	0.190	15.6	4.57	Ci.St. clouds at sunrise.
5	8:34 p.	0.165	16.7	5.79	5/10 Ci. 2/10 A.Cu.
6	8:47 p.	0.136	18.1	7.04	2/10 St.Cu.; some false cirrus.
7	9:31 p.	0.143	24.7	14.10	6/10 Ci.
8	10:49 p.	0.120	24.6	16.79	1/10 Cu.; 5/10 Ci.
9	8:58 p.	0.006	16.9	13.61	10/10 stratus.
9	9:28 p.	0.001	16.6	13.13	10/10 stratus; light fog.
10	9:00 p.	0.051	26.4	14.10	10/10 St.Cu.
11	9:13 p.	0.110	25.6	15.65	1/10 Ci.
12	8:49 p.	0.074	23.9	9.14	8/10 St.Cu.
13	8:40 p.	0.148	23.6	8.81	6/10 Ci.
14					Foggy.
15	8:34 p.	0.131	18.6	8.48	4/10 (Ci. and Cu.).
16	8:40 p.	0.201	16.7	4.17	1/10 Ci.
17	8:46 p.	0.188	16.9	6.27	3/10 Ci.
18					Rain.
19	8:33 p.	0.133	15.2	11.38	3/10 Ci.; 2/10 St.Cu.
20	8:39 p.	0.130	17.2	6.27	3/10 Ci.
21	8:34 p.	0.085	22.2	17.96	8/10 (A.Cu. and St.Cu.).
22	8:52 p.	0.052	22.8	14.10	10/10 St.Cu.
23	8:45 p.	0.078	23.3	15.11	9/10 St.Cu.
24	8:46 p.	0.117	28.1	17.37	1/10 Ci.; 1/10 A.Cu.; 1/10 St.Cu.
27	10:25 p.	0.182	22.2	16.20	1/10 Ci.
28	8:32 p.	0.130	25.0	16.79	3/10 A.Cu.; 2/10 St.Cu.
29	8:54 p.	0.144	16.2	8.81	2/10 Ci.; 2/10 A.Cu.
30	9:06 p.	0.151	19.4	8.48	Ci.St. over most of sky.

[5] *Abbot, C. G., & Aldrich, L. B.* The pyranometer—An instrument for measuring sky radiation. Smithsonian misc. col., Washington, 1916. **66**, No. 7.

[6] Views showing the character of the exposure at Mount Weather will be found in the MONTHLY WEATHER REVIEW for August, 1914, **42**, opposite p. 477, figs. 3 and 4.

TABLE 4.—*Summary of nocturnal radiation measurements at Mount Weather, Va.*—Continued.

Date.	Time.	*R.*	*t.*	*e.*	Remarks.
1914.	*H. m.*	*cal.*	°*C.*	*mm.*	
July 2	8:37 p.	0.139	22.1	9.83	2/10 Ci.; 1/10 A.St.; 1/10 St. Cu.
3	11:48 p.	0.076	19.4	13.13	9/10 St.Cu.
4	......	......	......	......	Rain.
5	8:34 p.	0.107	17.2	13.13	Light fog; 5/10 Ci.
6	8:42 p.	0.027	16.0	12.68	10/10 St.
7	9:06 p.	0.043	19.4	13.61	9/10 St.Cu.
8	8:50 p.	0.115	21.0	14.10	4/10 false cirrus.
9	8:35 p.	0.113	21.8	16.20	3/10 Ci.
10	8:38 p.	0.083	23.6	15.37	10/10 A.St.; clearing.
11	9:05 p.	0.073	25.6	14.60	6/10 St.Cu.
12	8:34 p.	0.124	26.9	12.68	3/10 Ci.
13	8:37 p.	0.068	20.8	14.10	10/10 St.Cu.
14	......	......	21.4	17.37	10/10 St.Cu.; rain.
15	8:36 p.	0.088	23.3	18.59	4/10 Ci.St.; 1/10 St.Cu.
16	8:49 p.	0.078	24.2	15.65	8/10 St. Cu.
17	8:53 p.	0.094	25.6	16.20	1/10 Ci.
18	8:50 p.	0.147	22.8	10.97	Few A.St.
19	9:02 p.	0.157	18.9	9.14	Few A.St.; dense haze.
20	8:39 p.	0.125	21.4	11.81	Few Fr.Cu.
21	9:05 p.	0.138	26.3	10.59	Light haze.
22	9:20 p.	0.104	23.9	15.65	2/10 Ci.
23	9:03 p.	0.059	28.5	11.81	10/10 St.Cu.
24	......	......	......	......	Rain.
25	11:03 p.	0.086	25.8	15.11	1/10 Ci.
26	8:46 p.	0.072	24.4	16.79	2/10 Ci.
27	9:32 p.	0.103	26.4	13.61	5/10 A.St.
28	8:31 p.	0.140	16.8	10.97	1/10 A.St. and St.Cu.
29	9:41 p.	0.099	16.3	8.18	7/10 St.Cu.
30	9:22 p.	0.135	13.3	9.83	4/10 St.Cu.
31	8:42 p.	0.130	19.4	7.87	3/10 A.Cu.
Aug. 1	8:50 p.	0.141	22.2	8.48	No clouds.
3	8:54 p.	0.133	19.7	11.38	2/10 Ci.St.
4	8:46 p.	0.107	19.4	12.68	3/10 Ci.
5	9:16 p.	0.102	19.3	13.13	1/10 Ci.St.; 1/10 A.Cu.; dense haze.
6	9:35 p.	0.110	21.1	15.65	1/10 Ci.St.; dense haze.
7	8:40 p.	0.126	25.7	14.60	3/10 St.Cu.; dense haze.
8	8:37 p.	0.118	26.8	15.11	4/10 St.Cu.
9	8:38 p.	0.070	26.6	16.20	10/10 St.Cu.
10	8:48 p.	0.049	22.5	15.93	9/10 St.Cu.
11	8:22 p.	0.040	22.4	16.20	10/10 St.Cu.
12	9:28 p.	0.100	17.1	13.61	2/10 St.
13	10:00 p.	0.143	20.0	9.47	No clouds visible.
14	8:22 p.	0.116	23.9	13.13	1/10 Ci.; 3/10 St. Cu.
15	8:40 p.	0.147	21.3	7.29	Few clouds on horizon.
16	8:20 p.	0.126	22.8	10.21	3/10 Ci. (over whole sky).
17	9:52 p.	0.137	24.2	10.59	Few clouds.
18	8:28 p.	0.136	26.9	13.13	Few cirrus.
19	9:32 p.	0.110	26.8	14.60	No clouds visible; stars faint.
21	8:28 p.	0.094	22.3	13.61	4/10 A.Cu.
22	8:52 p.	0.147	22.4	9.47	Light haze.
23	9:24 p.	0.146	26.0	15.11	No clouds visible.
29	8:22 p.	0.070	23.4	14.10	6/10 St.Cu.; distant lightning.
30	8:18 p.	0.124	21.1	11.38	Dense lower haze.
31	10:12 p.	0.116	22.8	12.68	5/10 Ci.
Sept. 1	8:08 p.	0.119	25.1	15.65	4/10 Ci.
2	8:02 p.	0.028	26.8	15.65	9/10 St.Cu.
3	8:28 p.	0.158	21.8	8.48	2/10 Ci.Cu., A.Cu. and St.Cu.
4	8:07 p.	0.147	14.2	8.81	Few St.Cu.
5	8:44 p.	0.149	17.9	8.18	2/10 Ci.
6	7:53 p.	0.084	23.5	12.24	5/10 A.Cu. and St.Cu.
7	8:14 p.	0.137	21.8	9.83	2/10 Ci.
8	8:02 p.	0.114	14.5	7.29	3/10 A.Cu.; 5/10 St.Cu.
9	7:56 p.	0.167	12.1	4.75	No clouds.
10	9:32 p.	0.139	14.5	5.79	5/10 Ci.
13	7:52 p.	0.135	12.7	7.57	No clouds.
14	8:20 p.	0.138	12.8	8.18	Do.
15	8:52 p.	0.169	14.3	6.76	Do.
15	10:32 p.	0.155	13.9	7.29	Do.
16	12:54 a.	0.146	11.2	8.58	Do.
16	2:23 a.	0.118	11.1	9.47	5/10 A.St.
16	8:08 p.	0.108	15.9	10.62	4/10 Ci.
17	8:16 p.	0.064	19.1	10.21	6/10 Ci.St.
18	8:00 p.	0.160	22.6	9.83	1/10 St.Cu.
19	......	......	......	......	Rain.
20	7:34 p.	0.105	20.7	10.21	1/10 Ci.
21	7:40 p.	0.147	24.4	13.13	1/10 Ci.
22	7:53 p.	0.148	25.7	12.24	1 Ci.
23	10:04 p.	0.123	24.3	14.10	2/10 Cu.Ni.
24	......	......	......	......	Rain.
25	7:38 p.	0.138	13.9	8.18	2/10 A.St. & St.Cu.
26	7:33 p.	0.147	11.8	5.56	Clear.
27	7:32 p.	0.075	16.5	6.04	6/10 St.Cu.
28	7:28 p.	0.146	13.6	3.81	Few Fr.Cu.
29	7:32 p.	0.157	14.5	5.79	Few Ci.St.; dense haze.
30	7:34 p.	0.150	17.2	6.50	Clear.

In Table 5 are summarized the radiation measurements made at the American University, Washington, D. C. Pyrgeometer No. 1 was employed in the measurements up to the end of January, 1915, but after that date most of the readings were made while comparing pyrgeometers Nos. 1_{bis}, 2, and 3. The instruments were exposed on the capstone of a ventilating flue of the College of History, at an elevation of about 137 meters above sea level. The exposure compares favorably with that at Mount Weather.

The instruments were usually placed in position about sunset, but the metal cap was not removed to expose the strips until just before the readings were made. About five determinations of i were usually obtained in each series of readings, and the values of R given in the tables were computed from the means of these readings. Both t and e were obtained from readings of a sling psychrometer whirled on the roof near the pyrgeometers.

TABLE 5.—*Summary of nocturnal radiation measurements made at Washington, D. C.*

[Gram-calories per minute per square centimeter.]

Date.	Time.	*R.*	*t.*	*e.*	Remarks.
1914.	*H. m.*	*cal.*	°*C.*	*mm.*	
Dec. 14	6:00 p.	0.162	−4.5	1.69	
15	6:02 p.	0.156	−8.3	1.78	
16	6:04 p.	0.152	−5.5	1.69	Clouds on horizon.
16	8:07 p.	0.130	−6.5	1.31	Trace of clouds on horizon.
17	6:00 p.	0.153	−2.3	1.07	Few Ci.
18	6:05 p.	0.143	0.6	1.96	Few clouds on horizon.
26	6:05 p.	0.152	−9.3	1.31	
26	8:27 p.	0.146	−11.5	1.07	
27	6:06 p.	0.128	−5.1	1.87	
27	7:14 p.	0.118	−5.7	1.60	1/10 clouds in west.
1915.					
Jan. 8	6:42 p.	0.156	4.9	3.99	
8	7:44 p.	0.155	4.6	3.99	
9	6:12 p.	0.142	7.3	4.75	Very hazy on horizon.
15	6:22 p.	0.183	7.8	3.81	
15	7:18 p.	0.172	6.6	3.81	
29	6:52 p.	0.160	−0.4	2.36	
29	7:16 p.	0.159	......	......	
29	7:54 p.	0.158	−1.9	2.16	Few A.St.; zenith clear.
Mar. 9	8:27 p.	0.184	3.4	2.74	
9	9:29 p.	0.173	......	......	
9	9:44 p.	0.172	3.3	2.87	
9	10:12 p.	0.172	......	......	
9	10:41 p.	0.175	......	......	
10	12:02 a.	0.175	3.2	2.74	
10	12:21 a.	0.159	......	......	
10	12.40 a.	0.158	......	......	
10	12:52 a.	0.166	......	......	
10	1:36 a.	0.164	......	......	
10	1:53 a.	0.162	2.3	2.62	
10	2:52 a.	0.157	......	......	
10	3:10 a.	0.159	......	......	
10	3:34 a.	0.155	......	......	
10	3:53 a.	0.152	1.0	2.87	
10	4:20 a.	0.158	......	......	
10	4:35 a.	0.165	1.7	3.81	
10	5:04 a.	0.165	......	......	
10	5:22 a.	0.163	0.7	3.00	
10	5:32 a.	0.158	......	......	
12	8:07 p.	0.176	0.9	2.49	
12	9:41 p.	0.177	......	......	
12	9:56 p.	0.188	......	......	
12	10:17 p.	0.194	1.2	1.69	
12	10:36 p.	0.193	......	......	
12	10:45 p.	0.180	0.6	2.06	
12	11:23 p.	0.206	......	......	Radiation unsteady.
12	11:56 p.	0.205	......	......	
13	12:21 a.	0.202	......	......	
13	12:36 a.	0.189	......	......	
13	12:54 a.	0.188	−1.1	2.48	
13	1:20 a.	0.175	......	......	
13	1:37 a.	0.179	......	......	
13	2:14 a.	0.178	......	......	
13	2:52 a.	0.168	−1.1	1.87	
13	3:19 a.	0.172	......	......	
13	3:45 a.	0.172	......	......	
13	4:08 a.	0.167	−1.1	1.96	
13	4:35 a.	0.169	......	......	
13	4:47 a.	0.166	......	......	
13	5:15 a.	0.161	......	......	
13	5:26 a.	0.162	−1.7	1.78	
13	5:42 a.	0.166	......	......	
14	8:00 p.	0.180	8.3	3.63	
26	8:06 p.	0.177	2.2	1.78	Cirrus formed after series.
27	8:13 p.	0.201	4.2	2.49	Hazy on horizon.
27	8:25 p.	0.181	......	......	
31	8:06 p.	0.167	3.3	3.45	Clouds forming.
Apr. 4	8:12 p.	0.185	8.4	2.99	
4	8:29 p.	0.191	......	......	
13	8:17 p.	0.156	7.7	5.16	
13	8:30 p.	0.152	......	......	
14	8:09 p.	0.176	12.7	3.54	Few clouds on horizon.
14	8:24 p.	0.193	......	......	
17	8:44 p.	0.193	13.5	3.63	
21	9:50 p.	0.145	16.2	5.36	Thin clouds; smoke.
24	8:28 p.	0.143	24.4	10.97	
24	8:51 p.	0.142	......	......	
24	9:51 p.	0.134	......	......	
24	10:00 p.	0.134	......	......	
24	10:40 p.	0.134	......	......	

In Table 6 the measurements made when the sky was apparently cloudless, or when at most only a few cirrus were visible, are grouped in accordance with the surface vapor pressure. There are also included in this table some measurements made on the top of Peak Knob, Ellijay, N. C., that are given in more detail in Table 9. But few of the above observations were taken under ideal sky conditions, however. Reference to "Remarks" in Tables 4, 5, and 9 will show that at some time on almost every night there were indications of the presence of clouds. While, therefore, it would be unwise to attempt to establish radiation laws from these observations, a consideration of their relation to laws already advanced will be of interest.

TABLE 6.—*Summary of clear-sky nocturnal radiations measurements.*

Date.	e.	T_1.	R.	σT_1^4.	$R/\sigma T_1^4$	ΔT.	R_{a30}.
	mm.	*°C.*	*cal.*	*cal.*		*°C.*	
Dec. 14	1.69	286.5	0.162	0.425	0.381	−30.3	0.373
15	1.78	264.7	0.156	0.402	0.388	−30.5	0.369
16	1.69	267.5	0.152	0.419	0.363	−28.6	0.384
16	1.31	266.5	0.130	0.413	0.315	−24.0	0.414
17	1.07	270.7	0.153	0.439	0.349	−27.5	0.393
18	1.96	273.6	0.143	0.458	0.312	−24.8	0.414
26	1.31	263.7	0.152	0.396	0.384	−30.2	0.372
26	1.07	261.5	0.146	0.383	0.381	−29.5	0.373
27	1.87	267.9	0.128	0.421	0.304	−23.3	0.421
27	1.60	267.3	0.118	0.418	0.283	−21.0	0.433
Means	**1.54**	**267.2**	**0.144**	**0.417**	**0.346**	**−27.0**	**0.395**
Mar. 12	1.69	274.2	0.191	0.463	0.412	−34.2	0.355
13	1.87	271.9	0.173	0.447	0.387	−31.3	0.370
13	1.96	271.9	0.170	0.447	0.381	−30.6	0.365
13	1.78	271.3	0.164	0.443	0.370	−29.6	0.380
26	1.78	275.2	0.177	0.469	0.377	−30.7	0.375
Means	**1.82**	**272.9**	**0.175**	**0.454**	**0.385**	**−31.3**	**0.369**
Jan. 29	2.36	272.6	0.160	0.452	0.354	−28.1	0.390
29	2.16	271.1	0.158	0.442	0.358	−28.4	0.388
Mar. 9	2.74	276.4	0.184	0.477	0.386	−31.8	0.370
9	2.87	276.3	0.172	0.477	0.361	−29.2	0.386
9	2.74	276.2	0.175	0.476	0.368	−29.5	0.381
10	2.62	275.3	0.163	0.470	0.347	−27.8	0.394
10	2.87	274.0	0.154	0.461	0.334	−26.5	0.402
12	2.49	273.9	0.188	0.460	0.409	−33.7	0.348
12	2.06	273.6	0.200	0.458	0.437	−36.7	0.339
13	2.48	271.9	0.188	0.447	0.421	−34.4	0.349
27	2.49	277.2	0.201	0.483	0.416	−34.9	0.352
Apr. 4	2.99	281.4	0.185	0.513	0.361	−29.7	0.386
Means	**2.57**	**275.0**	**0.177**	**0.468**	**0.379**	**−30.9**	**0.374**
Sept. 28	3.81	287.6	0.146	0.560	0.261	−19.6	0.446
Jan. 8	3.99	277.9	0.156	0.488	0.320	−25.5	0.410
8	3.99	277.6	0.155	0.486	0.319	−25.3	0.409
15	3.81	280.8	0.183	0.508	0.361	−29.8	0.385
15	3.81	279.6	0.172	0.500	0.344	−27.9	0.402
Mar. 10	3.81	274.7	0.162	0.466	0.348	−27.8	0.393
10	3.00	273.7	0.164	0.459	0.357	−28.6	0.382
14	3.63	281.3	0.180	0.512	0.352	−28.8	0.396
31	3.45	276.3	0.167	0.477	0.350	−28.2	0.392
Apr. 14	3.54	285.7	0.176	0.545	0.323	−26.7	0.408
17	3.63	286.5	0.193	0.551	0.350	−29.2	0.392
Means	**3.68**	**280.2**	**0.169**	**0.505**	**0.335**	**−27.0**	**0.401**
May 18	4.95	289.2	0.202	0.572	0.353	−29.0	0.390
18	4.57	288.9	0.202	0.570	0.354	−29.9	0.389
19	4.37	288.9	0.205	0.570	0.360	−30.5	0.386
19	4.57	288.6	0.205	0.567	0.362	−30.6	0.394
19	4.95	291.7	0.208	0.592	0.351	−29.9	0.391
20	4.95	289.7	0.194	0.576	0.337	−28.3	0.400
June 2	4.75	291.4	0.219	0.590	0.371	−31.9	0.379
3	4.37	290.8	0.191	0.585	0.326	−27.3	0.404
3	4.37	290.8	0.199	0.585	0.340	−28.7	0.398
3	4.57	289.9	0.203	0.578	0.351	−29.5	0.395
3	4.57	288.6	0.198	0.567	0.349	−29.5	0.392
3	4.95	288.6	0.197	0.567	0.347	−29.3	0.393
16	4.17	289.7	0.201	0.576	0.349	−29.6	0.392
Sept. 9	4.75	284.1	0.167	0.533	0.313	−25.5	0.414
May 5	4.95	285.2	0.169	0.541	0.312	−25.5	0.414
Means	**4.67**	**289.1**	**0.197**	**0.571**	**0.345**	**−29.1**	**0.396**
May 18	5.16	289.8	0.205	0.577	0.355	−30.1	0.389
20	5.16	289.7	0.193	0.576	0.335	−28.1	0.400
20	5.16	296.6	0.190	0.633	0.300	−25.3	0.422
Sept. 26	5.56	284.8	0.147	0.538	0.273	−21.8	0.437
29	5.79	287.5	0.157	0.559	0.281	−21.2	0.433
Apr. 13	5.16	280.7	0.156	0.508	0.307	−24.6	0.418
May 5	5.16	286.3	0.177	0.549	0.322	−26.6	0.399
5	5.16	285.8	0.178	0.546	0.326	−26.8	0.416
5	5.16	285.2	0.172	0.541	0.318	−26.0	0.411
10	5.61	280.2	0.177	0.504	0.351	−28.7	0.391
Means	**5.31**	**286.7**	**0.175**	**0.554**	**0.317**	**−25.9**	**0.412**
June 17	6.27	289.9	0.188	0.578	0.325	−27.1	0.407
Sept. 15	6.76	287.3	0.169	0.557	0.303	−24.9	0.420
30	6.50	290.2	0.150	0.580	0.259	−20.9	0.447
May 9	6.76	283.0	0.146	0.525	0.278	−22.1	0.435
9	6.76	282.4	0.146	0.521	0.280	−22.3	0.432
9	6.68	281.9	0.150	0.517	0.290	−23.0	0.428
9	6.68	281.3	0.152	0.512	0.297	−23.8	0.424
9	6.60	281.9	0.150	0.517	0.290	−23.0	0.428
10	6.27	282.4	0.159	0.520	0.306	−24.7	0.418
10	6.71	281.9	0.153	0.517	0.296	−23.6	0.424
10	6.07	280.2	0.173	0.504	0.343	−27.9	0.396
Means	**6.55**	**284.7**	**0.158**	**0.532**	**0.297**	**−23.9**	**0.424**
May 21	7.70	295.3	0.183	0.622	0.294	−24.6	0.425
22	7.87	293.8	0.152	0.609	0.250	−20.4	0.452
June 6	7.04	291.1	0.136	0.587	0.232	−18.7	0.464
Aug. 15	7.29	294.3	0.147	0.614	0.239	−19.4	0.459
Sept. 13	7.57	285.7	0.135	0.545	0.248	−19.6	0.454
15	7.29	286.9	0.155	0.554	0.280	−22.6	0.434
May 8	7.75	285.0	0.158	0.539	0.293	−23.8	0.426
8	7.29	284.7	0.168	0.537	0.313	−25.5	0.414
8	7.11	284.1	0.166	0.533	0.312	−25.2	0.415
9	7.39	283.6	0.149	0.529	0.282	−22.5	0.433
9	7.09	284.1	0.163	0.533	0.306	−24.8	0.418
Means	**7.40**	**288.1**	**0.156**	**0.564**	**0.277**	**−22.5**	**0.436**
May 31	8.48	293.0	0.173	0.603	0.287	−23.7	0.430
June 30	8.48	292.4	0.151	0.598	0.253	−20.6	0.441
Aug. 1	8.48	295.2	0.141	0.621	0.227	−19.2	0.466
Sept. 3	8.48	294.8	0.158	0.618	0.256	−21.0	0.449
4	8.81	287.2	0.147	0.557	0.264	−21.1	0.454
5	8.18	290.9	0.149	0.585	0.255	−20.6	0.449
14	8.18	285.8	0.138	0.546	0.253	−20.0	0.450
16	8.58	284.2	0.146	0.533	0.274	−22.0	0.427
25	8.18	286.9	0.138	0.554	0.249	−19.8	0.453
July 19	9.14	291.9	0.157	0.594	0.264	−21.6	0.444
Aug. 13	9.47	293.0	0.143	0.603	0.237	−17.8	0.460
22	9.47	295.4	0.147	0.623	0.236	−19.2	0.461
Sept. 7	9.83	294.8	0.137	0.618	0.222	−17.8	0.469
18	9.83	295.6	0.160	0.625	0.256	−21.1	0.449
Means	**8.83**	**291.5**	**0.149**	**0.591**	**0.252**	**−20.4**	**0.450**
July 18	10.97	295.8	0.147	0.626	0.235	−19.1	0.461
21	10.59	299.3	0.138	0.656	0.210	−17.2	0.476
28	10.97	289.8	0.140	0.577	0.243	−19.5	0.457
Aug. 16	10.21	295.8	0.126	0.626	0.201	−16.2	0.481
17	10.59	297.2	0.137	0.638	0.215	−17.5	0.473
July 20	11.81	294.4	0.125	0.614	0.204	−16.3	0.480
Aug. 3	11.38	292.7	0.133	0.600	0.222	−17.7	0.469
30	11.38	294.1	0.124	0.612	0.203	−16.1	0.481
Means	**10.99**	**294.9**	**0.134**	**0.619**	**0.217**	**−17.4**	**0.472**
Sept. 22	12.24	298.7	0.148	0.651	0.227	−18.7	0.466
Aug. 18	13.13	299.8	0.136	0.662	0.205	−16.8	0.480
Sept. 21	13.13	297.4	0.147	0.640	0.230	−18.8	0.465
June 7	14.10	297.7	0.143	0.642	0.223	−18.3	0.468
Means	**13.15**	**298.4**	**0.144**	**0.649**	**0.221**	**−18.2**	**0.470**
June 11	15.65	298.6	0.110	0.650	0.169	−13.6	0.500
July 22	15.65	296.9	0.104	0.630	0.165	−13.8	0.499
25	15.11	298.8	0.086	0.652	0.132	−10.4	0.523
Aug. 6	15.65	294.1	0.110	0.612	0.180	−14.2	0.495
23	15.11	299.0	0.146	0.654	0.223	−18.3	0.468
June 8	16.79	297.6	0.120	0.642	0.187	−15.0	0.490
27	16.20	295.2	0.182	0.621	0.293	−24.3	0.426
July 9	16.20	294.8	0.113	0.618	0.183	−14.5	0.493
17	16.20	298.6	0.094	0.650	0.144	−11.5	0.535
26	16.79	297.4	0.072	0.640	0.112	−8.7	0.535
Means	**15.94**	**297.1**	**0.114**	**0.637**	**0.179**	**−14.4**	**0.494**

The ratio $R/\sigma T_1^4$ which is given in column 6 of Table 6, shows variations with e and also with the season of the year. The maximum values—which are in excess of 0.40—were obtained in March, with low values of e, but not the minimum values. The minimum values of the ratio, which are less than 0.20, were obtained with maximum values of e.

If we subtract the measured values of R from σT_1^4, the remainder gives the effective radiation from the atmosphere, $R_a = \sigma T_2^4$ from which T_2 may be computed. In column 7 of Table 6, ΔT is the difference $T_2 - T_1$. Following Ångström,[7] the values of R_a have been

[7] *Ångström, A.* Op. cit., p. 42.

reduced to a uniform temperature of $T_1 = 293°$, by the equation

$$\frac{R_a}{R_{a20}} = \frac{T_1^4}{293^4}. \qquad (5)$$

The results are given in the last column of Table 6, and the mean values are plotted in figure 3, which also contains the mean values of R_{20}, or R reduced to $T_1 = 293°$, as above.

If, after allowing for the different values of σ employed by Ångström and myself, these plotted values of R_{20} are compared with Ångström's Bassour measurements,[8] it will be found that the values corresponding to vapor December, 1914, are markedly lower than the mean curve.

This is probably due at least in part to the vertical temperature gradient of the atmosphere at the time. In early winter, and especially with abnormally low surface temperature, the vertical gradients of both temperature and vapor pressure are small as compared with spring and early summer.[9] In consequence the effective radiation of the sky will be low.

The low values of R_{20} with high values of e may be due to the fact that the atmosphere was nearly saturated, and clouds may have been forming, although not distinguishable at night.

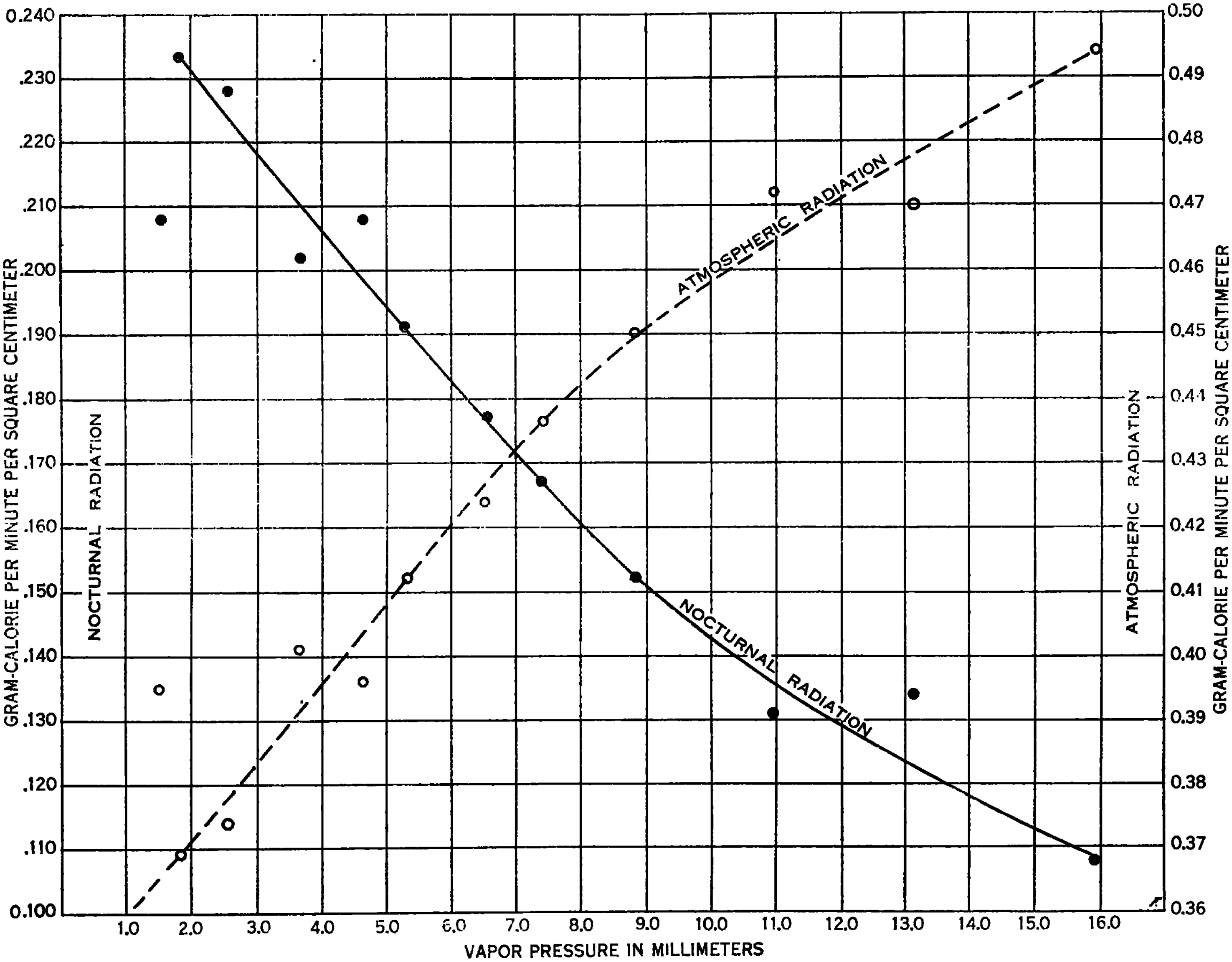

FIGURE 3.—Values of nocturnal or outgoing radiation, R_{20}, and of atmospheric radiation, R_{a20}, plotted against the observed surface vapor pressure, e.

pressures 1.82mm., 2.57mm., and 4.67mm., which are my maximum values, agree very closely with Ångström's curve. The remaining plotted values are lower than Ångström's, and the decrease in the value of R_{20} with increase in surface vapor pressure is greater than Ångström found it to be. It will be noted that the value of R_{20} corresponding to vapor pressure 1.54, which is based upon measurements all of which were made in

It is also of interest to note that during the latter part of May and early June, 1914, when high values of R were being measured, the atmosphere was filled with haze, or smoke from forest fires, so that solar radiation intensities were greatly reduced. Solar radiation intensities show that the atmosphere had cleared by June 16, but the values of R were not increased.

[8] *Ångström, A.* Op. cit., p. 36, fig. 3.

[9] *Blair, Wm. R.* Summary of the free-air data obtained at Mount Weather for the five years July 1, 1907, to June 30, 1912. Bull. Mount Weather Observatory, 1913, 6:111–194.

From Tables 4 and 5 it will be seen that on May 18–19, May 19–20, June 2–3, and September 15–16, 1914, and on March 9–10, and March 12–13, 1915, the radiation was measured at frequent intervals throughout most of the night. The series of September 15–16 was interrupted by clouds. Those of May and June show little variation in R throughout the night, except a pronounced drop just before sunrise. Those of March, 1915, show irregular variations, there being a pronounced decrease in the value of R about midnight of March 9–10, and an increase followed by a decrease on the night of March 12–13.

Several series extending from 8 p. m. to 5 a. m. were obtained in North Carolina during May, 1915 (see Table 9), but there was more or less cloudiness on every night.

It is also evident from Table 4 that while haze has no appreciable effect upon the radiation to the atmosphere, and that cirrus clouds have only a slight effect, clouds in the alto-cumulus level and below diminished the radiation markedly. In fact, on June 9, 1914, the instrument appeared to be receiving more heat from low stratus clouds than it was radiating to them. Table 7 gives other low values of radiation to cloud layers.

TABLE 7.—*Radiation to clouds.*

[Gram-calories per minute per square centimeter.]

Date.	R.	Clouds.
	cal.	
July 6	0.027	10/10 St.
Sept. 2	0.028	9/10 St.Cu.
Aug. 11	0.040	10/10 St.Cu.
July 7	0.043	10/10 St.Cu.

NOCTURNAL RADIATION MEASUREMENTS AT ELLIJAY, N. C.

During May, 1915, nocturnal radiation measurements were undertaken in North Carolina in connection with extensive frost studies that were being conducted there by Prof. H. J. Cox. Information was desired relative to the rate of radiation in the valleys, where frosts frequently occur, on the peaks, where the diurnal variations in temperature are small, and on the slopes, in the so-called thermal or frost-free belts.

Ellijay, N. C., was selected as the most favorable point for these measurements. On the north slope of Peak Knob (lat. 35° 11′ N., long. 83° 15′ W.) which rises abruptly from the narrow valley of Ellijay Creek, are located five Weather Bureau instrument shelters, each equipped with a maximum and a minimum thermometer and a thermograph. The elevations above sealevel, and the annual mean minimum temperatures at the different shelters, are shown in Table 8.

TABLE 8.—*Elevations above sealevel and annual mean minimum temperatures at Weather Bureau instrument shelters on Peak Knob, Macon County, N. C. (Lat. 35° 11′ N., long. 83° 15′ W.)*

Shelters.	Elevations.		Annual mean minimum temperatures.	
	Feet.	*meters.*	°*F.*	°*C.*
No. 1	2,240	683	41.2	5.1
No. 2	2,550	777	42.4	5.8
No. 3	2,860	872	44.3	6.8
No. 4	3,480	1,061	45.7	7.6
No. 5	4,000	1,219	44.8	7.1

Nocturnal radiation station **1**, was established beside instrument shelter 1, in the narrow valley of Ellijay Creek, and but a few yards from its bank. A tent kindly loaned for the purpose by the United States War Department was pitched beside the shelter, and in it were installed the galvanometer, the mil-ammeter, and other auxiliary apparatus, while the pyrgeometers were exposed on top of the instrument shelter. A similar installation, station **5**, was made beside shelter 5, which is on a shoulder just below the highest point on Peak Knob. Pyrgeometers Nos. 1_{bis}, 2, and 3, were employed in making the measurements, two of the instruments being installed at station **1**. After a night on which satisfactory observations were obtained the instrument at station **5** was exchanged for one of the instruments at station **1**. In this way all the instruments were compared.

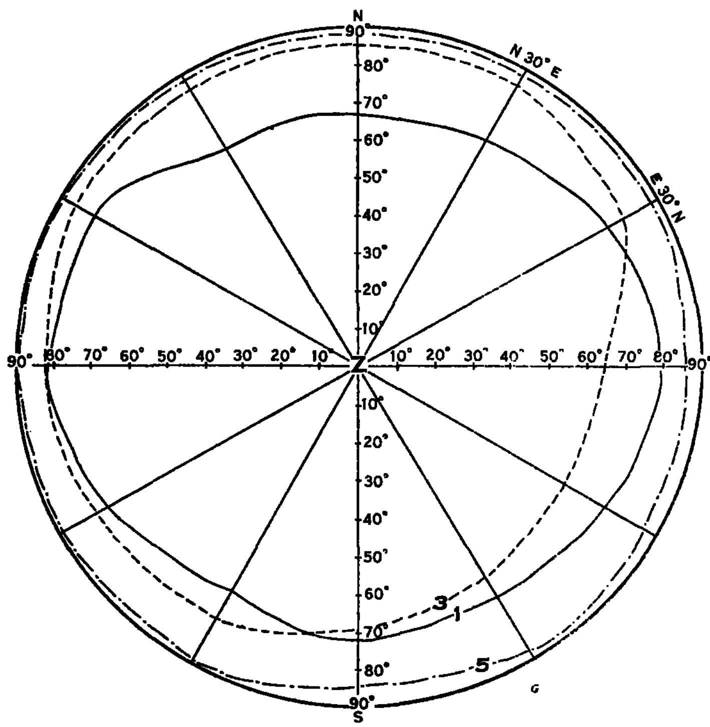

FIGURE 4.—Zenith distance of the sky line at radiation stations **1**, **3**, and **5**, Ellijay, N. C.

At first 10 readings were made with each instrument as nearly as possible on the hour (75th mer. time) from 8 p. m. to 5 a. m. The readings at station **5** were so even, however, that the number in a series was soon reduced to five. At the end of each series a sling psychrometer was whirled near the instrument shelter to obtain the air temperature and the dew point.

Table 9 contains a summary of the readings obtained at these two stations between May 5 and May 10, 1915. There are also added temperature readings obtained from the traces made by the thermographs in the instrument shelters. The traces have been corrected by comparison with the readings of the maximum and the minimum thermometers in each shelter. The vapor pressure obtained from a psychrometer reading at sunset at station **3** is also added.

TABLE 9.—*Temperature, vapor pressure, and noctural radiation measurements at Ellijay, N. C., during May, 1915.*

Date and time.	Temperature.				Vapor pressure.		Nocturnal radiation.		Notes.
	Station No. 1.		Station No. 5.						
	Shelter.	Psychrometer.	Shelter.	Psychrometer.	Station No. 1.	Station No. 5.	Station No. 1.	Station No. 5.	
1915. May 5–6:	°C.	°C.	°C.	°C.	mm.	mm.	cal.	cal.	
7:00 p. m.	15.0		16.1		*6.76				
8:00 p. m.	11.7		13.3						1/10 St.Cu.
8:22 p. m.	10.6		12.8				0.136	0.177	Clear.
8:30 p. m.	10.0	13.4	12.8		7.04				
9:07 p. m.	9.4		12.2				.122	.178	Do.
9:15 p. m.	8.9	11.1	12.2	12.7	7.04	5.16			
10:02 p. m.	7.8		12.2				.117	.169	Do.
10:10 p. m.	7.8	9.6	12.2	12.1	7.29	4.95			
11:08 p. m.	6.7		12.2				.103	.172	Few clouds.
11:15 p. m.	6.7	8.5	12.2	12.4	7.04	5.16			
12:10 a. m.	7.2		12.2				0.072	.130	Do.
12:20 a. m.	7.2	9.0	12.2	11.7	7.29	6.27			
1:05 a. m.	6.1		12.2				.096	.149	Do.
1:15 a. m.	6.1	7.8	12.2	12.0	7.04	5.21			
2:07 a. m.	5.6						.096	.143	Thin clouds.
2:20 a. m.	5.6	7.8	11.9	11.9	7.04	5.16			
3:07 a. m.	5.6		11.9				.074	.136	Increasing clouds.
3:15 a. m.	5.6	7.8	11.9	11.9	7.04	5.08			
4:05 a. m.	4.4		12.2				.092	.135	Thin clouds.
4:15 a. m.	4.4	6.7	12.2	12.3	6.76	5.16			
5:04 a. m.	3.9		12.2				.082	.163	Do.
5:12 a. m.	3.9	6.2	12.2	12.8	6.50	4.95			
May 6–7:									
7:00 p. m.	17.8		16.7		†9.80				
8:03 p. m.	17.2		16.7				0.074	0.091	10/10 St.Cu.
8:15 p. m.	16.7	18.9	16.7	16.0	9.65	8.48			
9:08 p. m.	19.4		17.2				0.035	0.046	Do.
9:20 p. m.	20 0	19.2	17.2	16.8	10.77	8.48			
10:00 p. m.	20.6	20.8	17.2	16.8	11.58	8.48	0.077	0.078	Do.
May 7–8:									
6:00 p. m.	14.4		12.2		*11.81				
8:15 p. m.	13.9	15.3	12.2		12.04		0.010		10/10 St.
10:05 p. m.	13.9	15.6	12.2		12.24		(‡)		Do.
1:00 a. m.	13.3	15.6	12.2		12.24		(‡)		Do.
May 8–9:									
7:00 p. m.	15.6		15.0		*8.48				
8:05 p. m.	12.8		13.6				0.122	0.151	2/10 clouds.
8:15 p. m.	12.8	13.8	13.3	13.2	10.21	7.29			
9:05 p. m.	11.1		12.2				0.122	0.158	
9:15 p. m.	11.1	11.9	12.2	11.7	9.30	7.75			
10:07 p. m.	9.4		12.2				0.115	0.168	
10:15 p. m.	9.4	10.8	12.2	11.7	8.99	7.29			
11:10 p. m.	8.9		11.7				[a]0.111	0.166	
11:20 p. m.	8.9	9.8	11.7	11.3	8.58	7.11			
12:10 a. m.	8.3		11.1				0.096	0.149	Few St. Cu. in N. to E. 12 p. m. to 3 a. m.
12:15 a. m.	8.3	9.4	11.1	10.7	8.36	7.39			
1:10 a. m.	7.8		10.6				0.092	0.146	
1:20 a. m.	7.8	8.9	10.6	10.2	8.00	6.76			
2:05 a. m.	7.2		10.0				0.090	0.146	
2:15 a. m.	7.2		10.0	9.2		6.76			
3:10 a. m.	6.7	8.1	10.0	9.1	7.42	6.68	0.097	0.150	
4:05 a. m.	6.1	7.7	9.4	8.3	7.42	6.68	0.080	0.152	
5:05 a. m.	5.6	6.9	8.9	8.9	7.16	6.60	0.079	0.150	
8:30 a. m.							(b)		
May 9–10:									
7:00 p. m.	15.0		12.8		*7.29				
8:05 p. m.	11.1		11.7				0.123	0.145	1/10 St.Cu.
8:15 p. m.	11.1	11.7	11.7	11.3	9.14	6.76			
9:03 p. m.	10.0		11.1				[c]0.120	0.126	Few St.Cu.
9:10 p. m.	10.0	10.6	10.6	10.2	8.64	7.37			
10:02 p. m.	8.9		10.6				0.108	0.163	Clear.
10:10 p. m.	8.9	9.7	10.6	11.2	8.18	7.09			
11:05 p. m.	8.3		10.6				[c]0.091	0.134	Few St.Cu.
11:10 p. m.	8.3	9.2	10.6	10.1	7.87	6.98			
12:03 a. m.	7.5	9.4					0.095	0.159	Clear.
12:10 a. m.	7.5	8.2	10.0	9.7	7.62	6.27			
1:08 a. m.	6.7		9.2				0.092	0.153	Do.
1:15 a. m.	6.7	7.3	9.2	9.0	7.14	6.71			
2:00 a. m.	5.8		8.3						
3:03 a. m.	5.3		8.1				0.098	0.173	Do.
3:10 a. m.	5.3	6.1	8.1	7.8	6.60	6.07			
4:00 a. m.	4.4		8.1						
5:05 a. m.	3.9		7.8				0.093	0.177	Clear; light fog in valley. Frost 1 mile up creek.
5:10 a. m.	3.9	5.0	7.8	7.2	6.07	5.61			

* Station No. 3.
† Station No. 3. Rain began at 10:30 p. m.; ended at 6:40 p. m., 7th.
‡ Less than 0.009.

a Dew on case of instruments at Station 1.
b Dew on tinfoil of both instruments under covers of cases when latter was taken off at 8:30 a. m.
c Dew on instrument shelter.

Date and time.	Temperature.				Vapor pressure.		Nocturnal radiation.		Notes.
	Station No. 1.		Station No. 3.						
	Shelter.	Psychrometer.	Shelter.	Psychrometer.	Station No. 1.	Station No. 3.	Station No. 1.	Station No. 3.	
1915. May 10–11:	°C.	°C.	°C.	°C.	mm.	mm.	cal.	cal.	
7:00 p. m.	18.9		16.7			8.48			
8:10 p. m.	13.9		15.6				0.120	0.120	2/10 clouds.
8:15 p. m.	13.3	13.1	15.6	15.7	9.65	8.23			
9:05 p. m.	11.7		15.3				0.101	0.108	
9:15 p. m.	11.7	12.3	15.0	15.6	9.45	7.75			
10:05 p. m.	11.1		14.4				0.094	0.111	Few Ci.St.
10:10 p. m.	10.8	11.6	14.4	15.2	8.53	7.90			
11:10 p. m.	10.0		13.9				[a]0.084	0.105	2/10 Ci.St.
11:15 p. m.	10.0	11.4	13.9	13.7	8.89	7.77			
12:10 a. m.	10.0		13.3				0.079	0.084	5/10 Ci.St.
12:15 a. m.	10.0	11.0	13.3	14.4	9.14	7.47			
1:02 a. m.	9.7		12.8				0.072	0.082	Cloudy but stars overhead.
1:10 a. m.	9.7	10.8	12.8	14.4	8.81	7.57			
2:00 a. m.	9.4		12.8				0.066	0.095	Sky nearly overcast with Ci.St.
2:05 a. m.	9.4	10.6	12.8	13.8	8.89	8.05			
3:05 a. m.	9.2		12.8				0.044	0.083	Cloudy, few stars visible.
3:10 a. m.	9.2	11.1	12.8	14.6	9.14	8.18			
4:07 a. m.	9.4		12.8				0.051	0.083	Cloudy, more stars visible.
4:15 a. m.	9.7	11.6	12.8	14.3	9.14	8.58			
5:10 a. m.	10.3		13.3				0.060	0.080	10/10 St.Cu.
5:15 a. m.	10.6	12.8	13.3	14.1	9.83	9.04			
May 12–13:									
7:00 p. m.	16.7		17.2			13.13			
8:08 p. m.	13.3		14.4				[a]0.099	0.114	2/10 St.Cu.
8:15 p. m.	13.3	13.8	14.4	14.9	10.92	11.30			
9:03 p. m.	11.9		12.8				0.084	0.112	1/10 St.Cu. [3 in NW.
9:10 p. m.	11.9	13.3	12.8	13.9	10.97	10.97			9/10 St.Cu.
10:05 p. m.	12.2		13.1				[b]0.033	[b]0.052	
10:10 p. m.	12.2	13.4	13.1	14.0	11.25	10.67			
11:10 p. m.	11.9		12.8				0.045	0.056	8/10 St.Cu.
11:15 p. m.	11.9	13.1	12.8	14.3	11.23	10.90			
12:15 a. m.	11.7		12.8				0.064	0.091	1/10 St.Cu.
12:20 a. m.	11.1	12.8	12.2	12.9	10.21	10.16			
1:05 a. m.	10.6		11.7				0.069	0.088	Few clouds.
1:10 a. m.	10.6	11.8	11.7	13.2	10.03	10.44			
2:04 a. m.	10.6		11.7				0.048	0.058	5/10 Ci. St.
2:10 a. m.	10.6	11.8	11.7	13.8	10.11	10.90			
3:03 a. m.	10.6		11.7				0.052	0.054	Stars brighter.
3:10 a. m.	10.6	11.7	11.7	13.3	10.11	10.46			
4:05 a. m.	10.0		11.1				0.021	0.026	More clouds.
4:10 a. m.	10.0	11.7	11.1	12.5	10.06	9.83			
5:08 a. m.	9.4		11.1				0.034	0.045	(c)
5:15 a. m.	9.4	11.0	11.1	12.1	9.35	10.16			
May 13–14:									
7:00 p. m.	18.3		20.6			10.59			
8:10 p. m.	14.4		18.3				0.104	0.132	Few Ci.
8:15 p. m.	14.4	15.6	18.3	19.3	11.81	10.87			
9:15 p. m.	13.3	14.9	16.7	17.8	11.23	10.01			
10:02 p. m.	11.9		15.0				[a]0.089	0.129	Clear.
10:10 p. m.	11.9	13.7	15.0	16.6	10.82	10.46			
11:01 p. m.	11.7		14.4				0.079	0.104	Few clouds.
11:07 p. m.	11.4	13.3	14.4	15.2	10.67	10.41			
12:03 a. m.	10.8		13.9				[b]0.082	0.129	Clear.
12:10 a. m.	10.8	12.8	13.9	15.7	10.16	9.98			
1:03 a. m.	10.3		13.3				[a]0.083	0.116	Do.
1:10 a. m.	10.3	12.1	13.3	14.1	9.91	10.26			
2:15 a. m.	10.0		12.8				0.070	0.117	Clear.
2:20 a. m.	10.0	11.5	12.8	13.8	9.75	9.98			
3:05 a. m.	9.4		12.2				0.073	[d]0.122	Do.
3:10 a. m.	9.4	11.1	12.2	13.2	9.22	10.06			
4:01 a. m.	8.9		12.2				0.071	[d]0.124	Do.
4:05 a. m.	8.9	10.6	12.2	12.9	9.04	9.96			
5:02 a. m.	8.9	10.3	11.7	12.9	9.02	9.80	0.081	0.122	Do.
5:05 a. m.	8.9	10.3	11.7	12.9	9.02	9.80			Few Ci., light fog in valley.
May 14–15:									
7:00 p. m.	19.4		20.0			13.61			
8:07 p. m.	16.7		18.9				0.083	0.126	Few Ci.
8:15 p. m.	16.1	17.1	18.9	19.4	13.46	12.24			
9:07 p. m.	14.4		17.2				[a]0.091	0.126	Clear.
9:12 p. m.	14.4	15.6	17.2	18.3	12.24	11.38			
10:00 p. m.	13.3								
11:05 p. m.	12.8		17.2				[b]0.078	[b]0.123	Do.
11:10 p. m.	12.8	13.6	17.2	17.1	10.97	11.74			
Midnight.	12.2		17.8						
1:05 a. m.	11.7		15.6				0.078	0.112	Do.
1:10 a. m.	11.7	12.8	15.6	16.1	10.36	10.74			
2:00 a. m.	11.4		15.6						
3:00 a. m.	10.6		15.3				0.062	0.112	Do.
3:05 a. m.	10.6	11.9	15.3	16.3	10.11	10.90			
4:00 a. m.	10.0		15.0						
5:01 a. m.	10.0		14.4				0.071	0.114	Few St.Cu., lt. fog in valley.
5:05 a. m.	10.0	11.1	14.4	14.7	9.40	11.12			

a Dew on shelter at No. 1.
b Dew on shelter and instruments.
c Few clouds, fog all about, but not at stations Nos. 1 and 3.
d Top of shelter at No. 3, damp.

On May 10 the equipment at station 5 was moved to a similar installation beside shelter No. 3, where readings were made until May 15. These also are summarized in Table 9.

With reference to the nocturnal radiation measurements it is to be noted that those obtained at station 1 are markedly lower than synchronous measurements obtained at station 5 and somewhat lower than synchronous measurements obtained at station 3. The following are some of the reasons why this should be so:

(1) As shown in figure 4, the sky line at station 1 averages about 20° above the true horizon. At station 3, between east and south it is about 25° above, and in other directions it is generally from 5° to 10° above. At station 5 the sky line is but little above the true horizon in any direction. From Ångström's determinations[10] of the radiation from a horizontal surface to different parts of the sky, the elevation of the sky line at station 5 does not have an appreciable effect on the radiation. At station 1 it reduces the radiation by about one-thirtieth, and at station 3 it reduces it by a somewhat less amount.

(2) With clear skies the thermometers in the instrument shelters at stations 1 and 3 systematically read lower than the dry-bulb thermometer of the sling psychrometer which was whirled near the shelter. As shown in Table 9, the depression in shelter 1 frequently amounted to more than 2 degrees C. and was to a temperature below that of the dewpoint determined from the sling psychrometer readings. That the temperature of the top of this instrument shelter was below the dewpoint temperature of the air was shown by a copious deposit of dew upon it, as is indicated by the notes in Table 9. These notes state that dew formed on the top

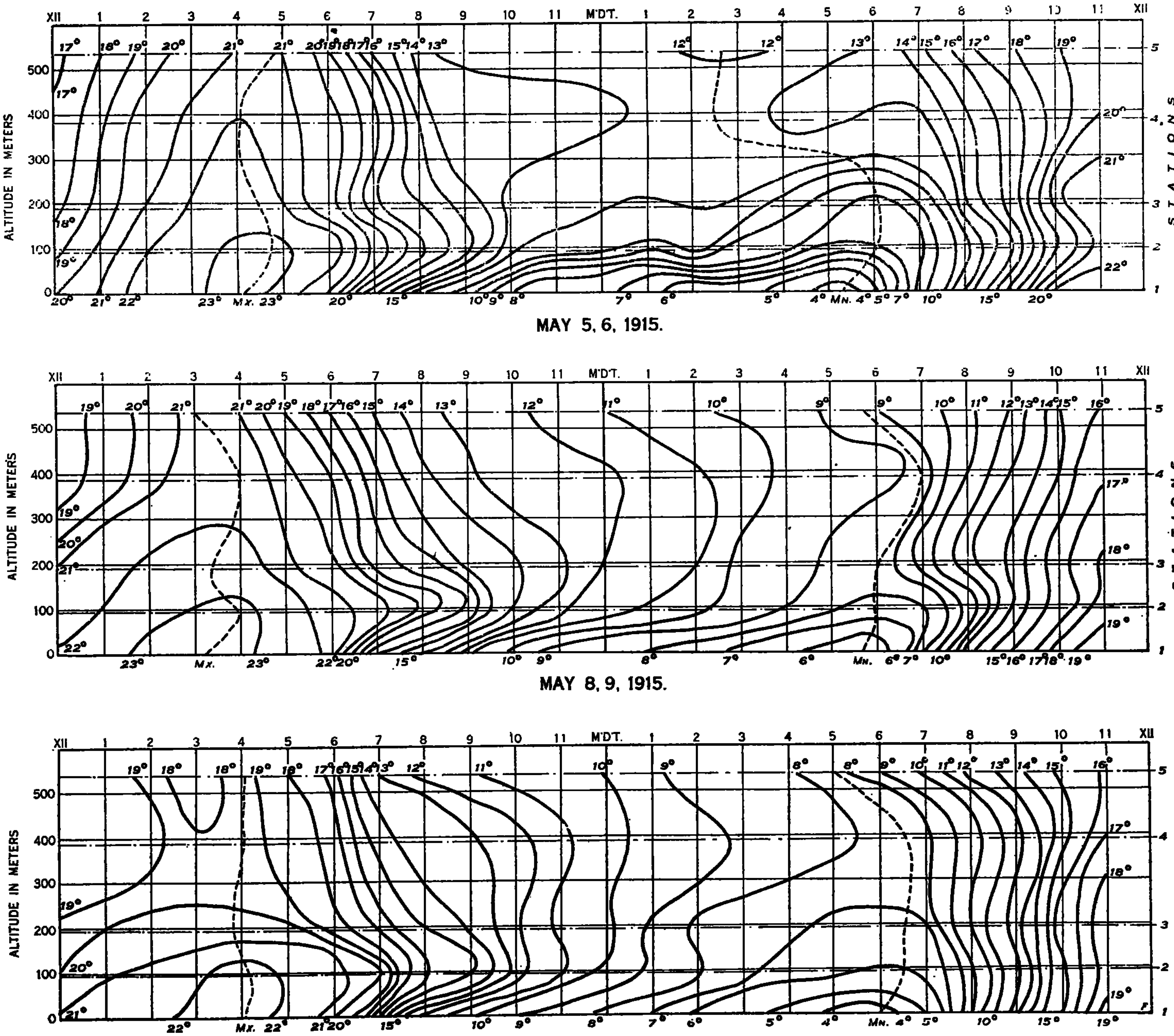

FIGURE 5.—Vertical temperature gradients on the slope of Peak Knob, Ellijay, N. C.

[10] Op. cit., p. 67, fig. 12.

of the shelter and on the cases of the instruments before midnight on nearly every clear night. On a few nights dew formed on both the shelter and the instrument at section 3, but it was not observed at station 5. While not actually observed, it is probable that when dew formed on the cases of the instruments it also formed on the radiating strips. The latent heat of condensation thus liberated neutralizes to some extent the cooling by radiation. Probably, also, the emissivity of the strips when wet is less than when dry.

(3) Figure 5 shows vertical temperature gradients on the mountain slope as determined from the corrected thermograph traces for the five stations. Blair [11] has shown that the temperatures on a mountain slope do not differ materially from free-air temperatures at the same levels. Therefore figure 5 gives at least approximately the air temperatures in the first 536 meters above station 1.

The nights of May 8–9 and May 9–10 were typical fair-weather nights. On the night of May 5–6 a warm wind at the upper station greatly retarded the nocturnal cooling, and the temperature commenced to rise about 2 a. m. This wind was not felt at station 1, where the nocturnal cooling continued until about 5 a. m. The result was a sharp inversion of temperature between stations 1 and 2, amounting to a rise of 5 degrees C. in 92 meters increase in elevation.

Comparing the isotherms of figure 5 with Blair's [12] "mean free-air temperatures," it is seen that at 4 p. m. the vertical temperature gradient from the valley station to the top of the mountain was about normal. By 8 p. m. the temperature had fallen so much more rapidly at station 1 than at the upper stations that it was now the coldest station, with a marked temperature inversion from stations 1 to 2. Station 1 continued to be the coldest station throughout the night, and by midnight or earlier station 4 had become the warmest station. The fall in temperature at station 1 was much less rapid after 8 p. m. or 9 p. m., at which time condensation set in, and psychrometer readings showed that the fall in the air temperature exceeded only slightly the fall in the temperature of the dewpoint.

In the narrow tortuous valley of Ellijay Creek it was the exception when any wind movement could be detected after nightfall. At station 5, near the top of Peak Knob, there was air movement throughout the night. At station 3, on the slope, a current from the south, or from the top of the mountain toward the valley, could usually be detected. Under the quiet conditions that prevailed at station 1 both the instrument shelter and the case of the pyrgeometer, as has been stated, cooled by radiation to a temperature below that of the dewpoint. It is probable that the strips of the pyrgeometer were at about the temperature of the thermometers in the instrument shelter. If we assume this to be the case, and make T_1 in equation (2) [p. 59] equal the absolute temperature of the thermometers in the shelter, then at times when there was no dew on the instrument, T_2 at station 1 was about 4 degrees C. higher than T_2 at station 5, if we correct the measurements of R at station 1 for the effect of the elevated sky line at that station.

[11] *Blair, Wm. R.* Summary of the free-air data obtained at Mount Weather for the five years July 1, 1907, to June 30, 1912. Bull., Mount Weather Obs., Washington, 1914, 6:118–124. (See section on mountain and valley temperatures.)

[12] *Blair, Wm. R.* Op. cit., p. 179, fig. 1.

The values of T_2 for station 3 do not differ materially from the values at station 1. It therefore appears that there is some effect, probably due to the elevated sky line of the valley and slope stations, that has not been entirely eliminated.

NOCTURNAL RADIATION MEASUREMENTS AT HIGHLANDS, N. C.

In an orchard on the south slope of Satulah Mountain, Highlands, N. C. (lat. 35° 02′ N., long. 83° 13′ W.), are located Weather Bureau instrument shelters 1 and 2, while in an orchard on the eastern slope of Dog Mountain, about 3 miles to the west, are located instrument shelters 3, 4, and 5. Table 10 gives the elevations above sea level and the annual mean minimum air temperatures at the different shelters.

TABLE 10.—*Elevations above sea level and annual mean minimum temperatures at Weather Bureau stations at Highlands, Macon County, N. C. (lat. 35° 02′ N., long. 83° 13′ W.)*

Shelter number.	Elevations.		Annual mean minimum temperatures.	
	Feet.	*meters.*	*°F.*	*°C.*
1	3,350	1,021	44.7	7.1
2	3,550	1,082	46.1	7.8
3	3,675	1,120	37.1	2.8
4	3,875	1,181	42.2	5.7
5	4,075	1,242	43.3	6.3

Shelter 2 is at the base of a rocky cliff about 800 feet high, the angular elevation of the top of which from the shelter is about 42°. To the west is a dense forest, and to the south and east the orchard slopes downward

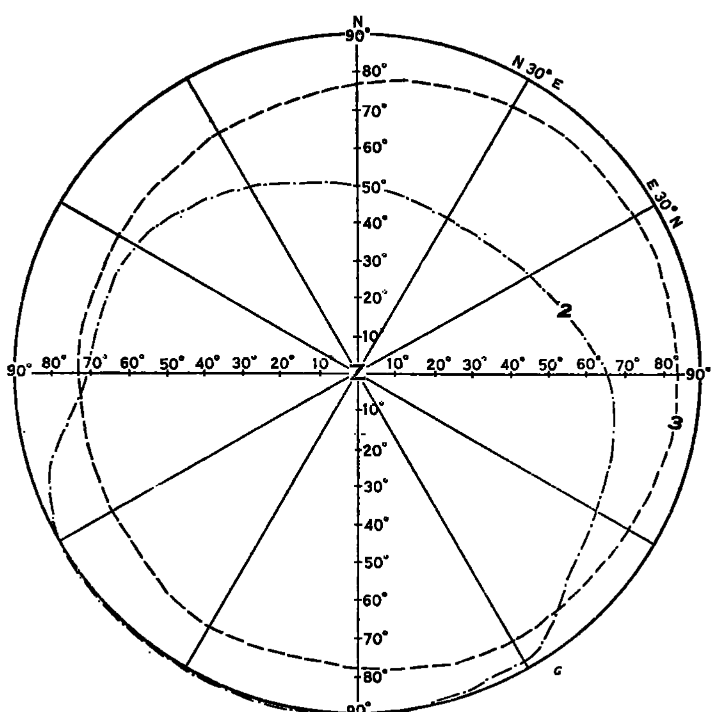

FIGURE 6.—Zenith distance of the sky line at radiation stations No. 2 and No. 3, Highlands, N. C.

toward Clear Creek Valley. The location of the shelter is such that it can receive radiation from the sun during almost the entire day, but at night nocturnal radiation is retarded by the cliffs and the forest trees.

Shelter 3 is on the edge of Buttermilk Level, a much broader mountain valley than that at Ellijay. It has the local reputation of being the coldest place in that part of the mountains.

Figure 6 shows the elevation of the sky line above the true horizon at shelters 2 and 3. From Ångström's diagrams [13] it does not appear that this should decrease the nocturnal radiation at station 3 by more than 2 per cent, but at 2 it may reduce such radiation by as much as 10 per cent. This would nearly equalize the readings at the two stations on the evening of May 17 (given in Table 11), which are the only reliable readings obtained at Highlands. The wind blew throughout the night of May 17–18, and light dew formed on the grass only, at station 3. On other nights the sky was less clear, there was little or no wind, and at station 3 there was a copious deposit of dew on the top of the instrument shelter and on the case of the pyrgeometer before midnight. Moisture globules were also observed on the radiating strips.

The value of R_{a30} for the evening of May 17 is about 5 per cent higher than Ångström's values for corresponding vapor pressures, and somewhat higher than those for station 5, Ellijay, N. C.

While the diurnal cooling at station 3 caused an inversion of temperature above that station it was not so marked as at Ellijay. It was of the same general character, however, and doubtless is to be attributed to the same cause, namely, continued surface cooling in a confined valley where there was little opportunity for mixing with warmer air, as is the case on the slopes.

RELATION BETWEEN RADIATION AND AIR TEMPERATURE.

The temperature of the air is very closely related to the temperature of the ground, which, in turn, is dependent upon the amount of heat received and absorbed during the day, and the rate at which heat is continuously given out. Of the heat received on a horizontal ground surface probably about 85 per cent is absorbed.

At Washington, during January, the mean daily surface temperature changes but little from day to day. The heat absorbed during the day must therefore about equal the losses from all sources. The average daily incoming radiation per square centimeter during this month is about 170 gram-calories, of which about 145 calories will be absorbed, or 0.10 calory per minute if distributed throughout the 24 hours.

At this season of the year with a clear sky the nocturnal radiation averages about 0.16 gram-calory per minute. If we assume that throughout the 24 hours and under all sorts of weather conditions the loss is 60 per cent of that measured by the instrument on clear nights, the outgoing radiation just balances the incoming radiation.

From the end of January to the end of June there is a steady increase in surface temperatures. During July they are nearly stationary again. At this time each square centimeter of surface receives on an average about 500 gram-calories of heat each day, and absorbs about 425 gram-calories, or 0.30 gram-calory per minute if distributed throughout 24 hours. The measured loss on clear nights is only about 0.20 gram-calory per minute. Consequently, at least half the heat received during the day must be carried away by convection, or expended in evaporation and other processes. By the end of October, when the incoming absorbed radiation has fallen to 225 gram-calories per day, or about 0.15 gram-calory per minute, it is noticeable that vertical convection has nearly ceased, as is shown by the absence of cumulus clouds.

[13] *Ångström, A.* Op. cit., page 67, figure 12.

TABLE II.—*Temperature, vapor pressure, and nocturnals radiation measurements at Highlands, N. C., during May, 1915.*

Date and time.	Temperature.				Vapor pressure.		Nocturnal radiation.		Notes.
	Station No. 2.		Station No. 3.		Station No. 2.	Station No. 3.	Station No. 2.	Station No. 3.	
	Shelter.	Psychrometer.	Shelter.	Psychrometer.					
May 17–18.	°C.	°C.	°C.	°C.	mm.	mm.	cal.	cal.	
7:00 p. m.	16.1		13.3		*9.47				
8:10 p. m.	13.9		12.2				0.127	0.158	Clear.
8:25 p. m.	13.9	13.9	12.2	13.5	10.59	7.29			
9:05 p. m.	12.8		11.1				0.133	0.151	Do.
9:10 p. m.	12.8	13.1	11.1	12.5	8.33	7.42			
10:10 p. m.	12.2		9.4				0.128	0.150	Do.
10:20 p. m.	12.2	12.5	8.9	10.7	8.03	6.50			
11:02 p. m.	10.6		8.9				0.122	0.136	Do.
11:10 p. m.	10.6	11.1	8.9	8.9	8.00	6.76			
12:05 a. m.	11.7		8.3				0.126	0.138	Do.
12:10 a. m.	11.7	12.8	8.3	9.1	7.29	6.83			
1:10 a. m.	12.2		8.3				0.123	[a]0.127	Do.
1:15 a. m.	12.2	12.8	8.3	10.4	7.39	7.67			
2:10 a. m.	12.2		6.1				0.109	0.111	Do.
2:15 a. m.	12.2	12.5	6.1	6.8	7.16	7.11			
3:10 a. m.	12.8		5.6				0.041	0.069	5/10 Cu.St.
3:30 a. m.	12.8	13.3	5.6	5.9	6.50	6.58			Few A. Cu.
4:02 a. m.	11.9		4.4				0.112	0.074	
4:10 a. m.	11.9	12.9	4.4	4.9	6.81	6.17			5/10 A. Cu.
5:02 a. m.	11.7		4.4				0.079	[d]0.012	
5:05 a. m.	11.7	12.8	4.4	6.1	6.78	6.60			
6:05–6:30									Lt. rain.
May 18–19.									
7:00 p. m.	17.8		17.2		*10.21				
8:04 p. m.	17.2		13.9				0.105	0.086	
8:10 p. m.	17.2	18.2	13.9	13.8	11.38	10.14			6/10 St. Cu.
9:10 p. m.	15.6		11.7				0.113	[e]0.094	Clear.
9:15 p. m.	15.6	17.2	11.7	11.9	11.12	9.55			
10:04 p. m.	15.6		10.6				0.108	[b]0.074	Few Ci.
10:10 p. m.	15.6	16.7	10.6	10.9	10.67	9.37			
11:00 p. m.	16.1		9.4				0.117	0.058	Few St.Cu.
11:05 p. m.	16.1	16.8	9.4	9.6	11.43	8.56			
12:10 a. m.	16.1		8.9	8.9		8.18	0.098	[c]0.036	
12:20 a. m.	16.1	16.9	8.9		10.77				
1:04 a. m.	16.1		8.3	8.7		8.31	0.087	([e])	3/10 Ci.
1:10 a. m.	16.1	16.9	8.3		11.38				1/10 A.Cu.
2:10 a. m.	16.1		8.3				0.100		
2:15 a. m.	16.1	17.3	8.3		11.56				5/10 A. St.
3:00 a. m.	15.6		8.3	9.2		8.38			
3:08 a. m.	15.6	17.2	8.3		11.81			([f])	
May 21:									
7:00 p. m.	17.8		15.6		*10.97				
8:10 p. m.	17.2		14.4	14.4		11.46	0.088	0.086	
8:15 p. m.	17.2	17.5	14.4		12.24				9/10 St.Cu.
9:05 p. m.	16.7	17.2	13.3	13.3	11.81	10.72	0.065	0.050	5/10 St.Cu.
10:00 p. m.	17.2		12.2	11.7		10.44		[b]0.024	
11:00 p. m.	17.2	17.2	11.7	11.7	12.50	9.83	0.059	[b]0.049	6/10 St.Cu.
May 22–23:									
7:00 p. m.	16.7		17.2		*13.61				
8:05 p. m.	16.7		15.0						Few clouds.
8:10 p. m.	16.7	17.0	15.0	14.6	13.41	11.51	0.091	[a]0.093	
9:10 p. m.	16.7		13.3	13.1		10.90			Few Ci.
9:15 p. m.	16.7	16.7	13.3		12.78		[b]0.088	[b]0.052	
10:10 p. m.	16.1		12.2						
10:15 p. m.	16.1	15.7	12.2	12.1	12.37	10.36	0.091	[d]0.050	Lt. fog.
11:00 p. m.	15.6		12.2						
11:05 p. m.	15.6	15.4	12.2	12.9	11.81	10.82	[c]0.080	0.054	
12:15 a. m.	15.6		11.1						
12:20 a. m.	15.6	15.7	11.1	11.3	12.37	9.83	0.078	0.054	Lt. fog.
1:05 a. m.	15.6		10.0						
1:15 a. m.	15.6	15.6	10.0	10.1	12.24	9.07	0.085	0.030	
2:15 a. m.	15.0		9.4						
2:25 a. m.	15.0	15.4	9.4		12.04		[g]0.084		
3:03 a. m.	14.4		8.3						
3:10 a. m.	14.4	15.0	8.3	9.0	11.81	8.31	0.074	0.030	
4:15 a. m.	14.4		8.3						
4:30 a. m.	14.4	14.4	8.3		11.30		0.096		
5:07 a. m.	15.0		7.2						
5:15 a. m.	15.0	15.0	7.2	8.0	11.23	7.87	0.091	[h]0.031	10/10 Ci.St. & St.Cu.
May 23–24:									
7:00 p. m.	20.0		20.0		*15.65				
8:00 p. m.	17.8		18.3						Rain, [illegible]
9:05 p. m.	17.8	18.1	16.7		14.60		0.043	0.056	6/10 St.Cu.
9:10 p. m.	17.8		16.7	15.1		12.42			
10:05 p. m.	17.8	17.8	15.0		14.10	11.76	0.087	0.068	2/10 St.Cu.
10:10 p. m.	17.8		15.0	14.3					
10:57 p. m.	17.2		14.4				0.075	[c]0.076	
11:00 p. m.	17.2	16.9	14.4	16.0	13.87	13.03			2/10 St.Cu.
12:04 a. m.	16.1		15.0				0.094		
12:15 a. m.	16.1	16.2	15.0		12.80				
1:02 a. m.	15.6		13.9				0.054	0.042	2/10 clouds.
1:07 a. m.	15.6	15.3	13.9	13.4	12.04	10.97			
3:02 a. m.	15.0		11.7				0.091	0.054	
3:10 a. m.	15.0	15.3	11.7	11.0	11.76	9.35			
5:00 a. m.	16.1		8.9				0.068	0.034	7/10 St.Cu.
5:05 a. m.	16.1	16.1	8.9	9.3	13.13	8.56			Fog in valley.

* Station No. 1.
[a] Dew on grass.
[b] Dew on instrument shelter.
[c] Dew on case of pyrgeometer.
[d] Dew on instrument shelter and case of pyrgeometer.
[e] Less than 0.010.
[f] Rain began 4:45 a. m.; ended before 6:20 a. m.
[g] Dew evaporated from case of pyrgeometer.
[h] Small globules of water on black strips; outside of the pyrgeometer case dripping wet.

Reference to Blair's mean free-air temperatures [14] shows that the vertical temperature gradient is steeper during the spring than during the fall. In May, for example, the fall in temperature in 5 kilometers is 32 degrees (C.); in September it is 26 degrees. In conformity with the above in the spring nocturnal radiation is greater than in the fall, the intensity of solar radiation is a little greater, and so is the diurnal range of temperature.

Temperature inversions like those shown in figure 5, are not rare. They may occur on a plain where there is no wind movement to carry away the lower cooled air layer and mix it with warmer air. They are to be expected in deep valleys unless the valley grade is such that the cold air will flow out rapidly. The so-called thermal belts, or belts on the slopes that are free from injurious frosts at critical times, are due to the fact that as soon as the surface air layer on the slope becomes cooled there is a convective exchange between it and warmer adjacent air that may have been on the same level, but was farther removed from the slope surface.[15]

On the slope of Peak Knob frosts injurious to fruit are unknown between the 200-meters and the 400-meters levels, while fruit can not be raised in the valley at the foot of the slope.

I wish to acknowledge my indebtedness to Dr. (now Maj.) William R. Blair for valuable suggestions and assistance in connection with the test of pyrgeometer No. 1 at Mount Weather, Va.; to Mr. Roy N. Covert, who assisted in the standardization of pyranometers No. 1_{bis}, No. 2, and No. 3, at Washington, D. C., made the drawings for figures 1 and 2, and made all the readings at radiation stations No. 3 and No. 5, Ellijay, N. C., and at No. 3, Highlands, N. C.; and to Mr. I. F. Hand, who made many of the radiation measurements at Mount Weather, Va., and Washington, D. C.

[14] *Blair, Wm. R.* Op. cit., p. 179, fig. 1.
[15] *Marvin, Chas. F.* Air drainage explained. MONTHLY WEATHER REVIEW, October, 1914, **42**: 583–585.

MOLECULAR SCATTERING OF LIGHT.

[*Reprinted from* Nature, London, Feb. 14, 1918, **100**: 473.]

In a paper communicated to the Astronomical Society of France (L'Astronomie, January), Prof. *Ch. Fabry* gives an account of Lord Rayleigh's explanation of the blue coloration of the sky, and announces that the theory has been experimentally verified in his laboratory at Marseilles by M. Cabannes. Prof. Fabry suggests that several hitherto mysterious phenomena in the heavens may possibly be explained as effects of this scattering of light by gaseous molecules. In the case of the solar corona, for example, the portion of the luminosity which gives a continuous spectrum does not necessarily imply the presence of solid or liquid particles, but may be attributed to the diffusion of photospheric light by molecules of truly gaseous coronal matter. A density of only 1/1,000,000,000 part of that of atmospheric air would suffice to account for the observed intensity of the coronal light, and the polarization of the light would be simply explained, as in the case of the light of the sky. A part of the luminosity of the tails of comets may be explained in a similar manner, and in this case the density must be less than one milligram per 1,000 cubic meters, as otherwise the luminosity would be greater than any which has ever been observed. Other possible effects of molecular scattering are also suggested. It may be added that Prof. R. J. Strutt has also succeeded in observing the scattering of light by dust-free air in a laboratory experiment with artificial illumination (Nature, Oct., 1917).[1]

[1] Reprinted in this REVIEW, October, 1917, p. 485.