DETERMINATION OF THE CONSTANT.

Experiments having shown that different instruments, constructed according to the idea explained above, read parallel to one another within 2 per cent, the radiation being computed from the formula:

$$R = c\,i^2 \qquad (1)$$

it remained highly desirable to determine the constant c in order that the readings may be directly transferred into gm. cal. per cm.^{2} per min., i. e., the usual actinometric unit.

A preliminary value of the constant c in (1) was obtained through a comparison between the sky actinometer and the Ångström pyrheliometer Nr. 158,[6] both being exposed to the sun radiation only. Comparisons on various occasions gave values ranging from 8.5 to 8.7, the mean value being 8.61. This value can, however, be considered only as a rough approximation when applied to the sky radiation measurements, since the qualities of the two radiations are different, the sun radiation being strong, the luminous sky radiation weak, in the infra red. It is consequently to be expected that the value of β in (2) will be slightly different for the sky radiation from what it is for the radiation from the sun. This difficulty which was overcome through comparing the indications of the sky actinometer with those of the pyrheliometer, when they both were exposed to a "filtered" sun radiation of approximately the same wave-length distribution as in the sky light. For a filter I used a combination of a blue glass (Schott & Genossen Nr. F 3086) and a water screen 1.5 cm. in thickness. The constant obtained in that way is 8.42, which is slightly lower than the preliminary value. This is to be expected since β has a higher value for the long-wave radiation partly entering in the sun radiation, than for the short waves.

A comparison between this instrument and the pyranometer of Abbot and Aldrich showed that the difference between the readings of the two instruments is less than 2 per cent. Individual readings differ, however, by as much as 6 per cent due, according to my opinion, to the fact that the pyranometer readings are influenced by the heating of the glass screen.

A comparison with the Callendar recording instrument used at the observatory of the U. S. Weather Bureau, under the direction of Professor Kimball, showed also a satisfactory agreement in the averages. The Callendar readings were, however, under conditions of very calm weather, undoubtedly influenced by the heating of the glass, the convection of the heat from the glass through the air being then small. The effect is generally not a large one, but may under special conditions amount to as much as 10 per cent.

The results of a number of measurements with the newly constructed instrument, with the object of determining the radiation from a clear sky for different heights of the sun and for different transmission powers of the atmosphere, as well of studying also the influence of clouds upon sky radiation, are under preparation and will probably soon be published. In the meantime, I take the opportunity to express my sincerest thanks to Director Marvin and the staff of the U. S. Weather Bureau for the facilities afforded me during my stay at the Bureau in July and August, 1919. Especially to Prof. H. H. Kimball I am indebted for his kind assistance in mounting and comparing the different instruments and for the facilities afforded me at his observatory in general.

[6] The constant of this instrument as determined at Upsala is 13, 58: the difference os its reading from the Smithsonian scale is 4,58 per cent. See "Notes on comparison between pyrheliometers, etc., this REVIEW, p. 798-799.

SOME PROBLEMS RELATING TO THE SCATTERED RADIATION FROM THE SKY.

By ANDERS ÅNGSTRÖM.

[Dated: Geographical Institute, Bergen, Norway, September, 1919.]

The knowledge of the optical phenomena exhibited by the sky has always been considered of high value for the local forecasting of weather. Thus a dark blue sky shows that there are few diffusing particles in the atmosphere and generally a low content of water vapor. On the contrary a milky-white sky indicates that the atmosphere contains a large number of diffusing particles and generally that the content of water vapor is great. The latter is apt to be the case also when the sunset is very red, which shows that then the atmosphere, at least in the west, must have a high diffusing power. These are well-known facts, only to be briefly referred to here.

One of the special questions falling under the problem of the optics of the sky, is this: How do the various changes in the properties of the sky affect the direct heat income to the surface of the earth? From a theoretical point of view the actinometry of the sky has shown itself most fruitful in clearing up our ideas in regard to the construction of different atmospheric layers as well as to the properties of gases and diffusing particles under the action of light in general. Thus, the investigations of Abbot and Fowle[1] upon the scattering effect of the cloudless atmosphere upon the sun radiation have shown, in combination with Lord Rayleigh's theory for scattering in gases, that the scattering of the atmosphere above about 3 kilometers altitude is caused mainly by the effect of the molecules. Below that level the dust atmosphere, increasing in density with depth, plays an important part in the weakening of the sun radiation. First the spectro-bolometric studies of the sun radiation have given us an idea of the amount of energy stored up through absorption in different atmospheric layers and have made it possible to explain, at least in its general features, the temperature distribution in the upper-air layers, and at first view its rather astonishing feature of the great inversion.[2]

We know the total heat radiated to a horizontal surface by sun and sky to be of prime importance in determining the temperature distribution in its relation to time as well as to coordinates. Several investigations have been carried out on the radiation from the sun; and its variation with zenith-distance of sun, with altitude, water vapor, and diffusing power of the atmosphere, may at present be said to be relatively well known, even if much is yet to be done before the relation between sun radiation and climate is revealed to us more in detail. Angot has computed the solar radiation on a horizontal surface at different latitudes for different transmission coefficients of the atmosphere, the transmission assumed to be constant over the surface of the earth. It is one of the objects of pyrheliometry to revise the latter assumption according to actual conditions. But the computation of Angot and his followers has not taken into consideration the important part played by the diffuse sky radiation, the observations of which are few and generally of accidental character. The observations show, however, that the radiation from the sky is relatively large, that for high sun, clear sky, and medium diffusing power it is about 20 per cent of the solar radiation, but that its percentage increases rapidly for increasing zenith distance of the

[1] Annals of the Astrophysical Observatory of Smithsonian Institution, Vol. III.

[2] *R. Emden:* Über Strahlungsgleichgewicht und atmosphärische Strahlung. (Sitz. ber. d. Bayerischen Akad. d. Wissenschaften München, 1913.)
W. J. Humphreys: Astrophys. Journal. Vol. XXIX.
E. Gold: Proc. Roy. Soc. of London, ser. A 1909.

sun and with increase in cloudiness. In the first place under the more simple conditions presented by a clear sky, one of the prime objects of sky actinometry ought to be to fix the relation between the radiation from the sky on the one hand and the height of the sun and diffusing power of the atmosphere on the other. Here a comparison between the observations and the theory of L.V. King may be of value, and may lead to a conception of the ratio between the amount of radiant energy diffused by the dust particles and the amount transformed by them into heat. A close agreement between observations and the theory named is not to be expected without an extension of the theory or an adjustment of the observations, while the reflection of the light from the earth's surface introduces a complication not considered in the theory. This is probably the reason why Aldrich,[1] observing in California, found a more rapid decrease in the sky radiation than demanded by the theory.

From the climatological point of view the influence of clouds upon the heat exchange is naturally of great importance, though very difficult to subject to general rules. The cloud-forms are innumerable and the influence of different clouds exhibits great variations. From my observations at Upsala, with the instrument described above in the summer of 1918, and at Washington in the summer of 1919, I have drawn up the following table, wherein the numbers ought only to be taken to be what they are—the average of some few cases.

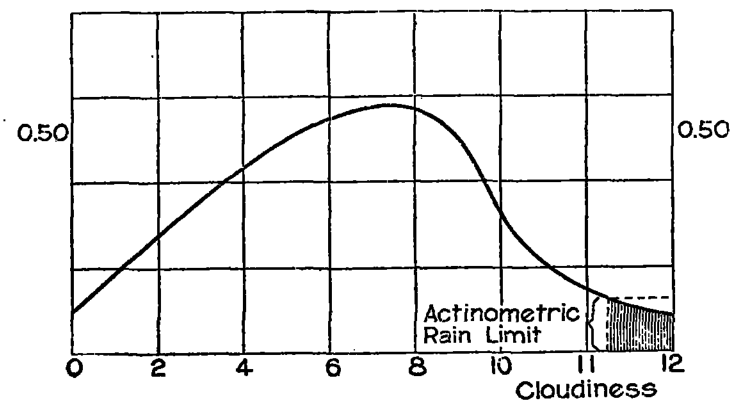

FIG. 1.—Variation in sky radiation with cloudiness.

TABLE 1.—*Variation in sky radiation with cloudiness.*

(Sun's zenith distance 10°-30°.)

	R. gr. cal. / cm². min.	dR / dn
(1) Radiation from clear sky:		
(a) Transmission for sun radiation about 0.75	0.10	+
(b) Transmission for sun radiation about 0.50	0.30	+
(2) Sky covered by Ci-St	0.15-0.30	+
(3) Sky covered by A-St	0.20-0.40	+
(4) Sky covered by St-Cu (not very dense), about	0.50	±
(5) Sky covered by Nb (not very dense), about	0.35	−
(6) Sky covered by Nb (very dense)	0.10	−

The table shows some interesting and important features. With increasing density [n = nebulosity] of the cloud sheet the radiation from the sky first increases in order to reach a maximum, after which it decreases with increased heaviness of the cloud. For the cloudiness corresponding to the maximum of sky radiation, the sun radiation is practically nil. The radiation income corresponding to the cloudiness 10 is consequently under these conditions not equal to 0, as is often assumed, but about 50 per cent of the sun radiation when the sky is clear. On the average the cloudiness 10 causes a decrease in the total heat income down to about 30 per cent. In regard to the influence of cloudiness upon the total heat income, I have given a survey of the question, just published in the *Meteorologische Zeitschrift*,[3] on the basis of Kimball's observations with the Callendar recording-instrument. A more detailed treatment of the question will soon appear by Prof. Kimball himself.[4] The superposition of the diffused sky radiation upon the direct radiation from the sun is, in large part, the reason that the heat income at the cloudiness 5 (or 50 per cent) is nearly 80 per cent of the heat income for clear sky.

After the maximum is reached an increased cloudiness causes a decrease in the radiation from the sky. When the radiation from the sky has reached a certain low value—not very different from the value corresponding to a clear sky—rain generally begins to fall. This actinometric rain limit is naturally dependent upon the height of the sun above the horizon, but seems, for uniformly clouded sky and constant solar height, to maintain a value that fluctuates only between narrow limits. For the local forecasting of rain a closer investigation of these conditions may prove to be of value.

Purely physical and mathematical problems may be solved by one single investigator limited to a certain place and, in regard to time, dependent only upon the rapidity of the work of the investigator's brain or his experimental speed and skill. But meteorological problems need for their solution many observers distributed over wide areas and continuing their work over considerable intervals of time. If the present paper has been able to draw attention and attach interest to some of the wide problems offered by the actinometry of the sky, it will have filled its purpose.

[1] Aldrich, L. B. The Smithsonian eclipse expedition of June 8, 1918 (Smithsonian Misc. coll., No. 9, 1919).

NOTE ON COMPARISONS BETWEEN PYRHELIOMETERS AND ON THE DIFFERENCE BETWEEN THE ÅNGSTRÖM STANDARD AND THE SMITHSONIAN STANDARD.

By Dr. ANDERS ÅNGSTRÖM.

[Dated: Meteorological Bureau, Stockholm, Sweden, October, 1919.]

The constant of the Ångström pyrheliometer No. 158, used by myself during expeditions to Algeria and California, was determined in 1912 from measurements of the width and resistance of the strips and found to be 13.58.[1] Using this value of the constant, the instrument was found to read 1.25 per cent lower than the standard instrument of the solar observatory at Upsala $\left[\frac{\text{Å 158}}{\text{Å. S.}}=0.9875\right]$, which we will indicate in the following by the Ångström Standard (Å. S.).[2] Shortly afterwards (in the summer 1912) the pyrheliometer No. 158 was compared by Dr. Abbot and myself with a newly standarized secondary pyrheliometer of the Smithsonian, (A. P. O. 9), and later by Dr. Abbot with the Smithsonian secondary standard itself (A. P. O. 8. bis.). The results of these comparisons were that No. 158 read 4.58 per cent ± 0.15 lower than the Smithsonian standard (*S. I. S.*) $\left[\frac{\text{S. I. S.}}{\text{Å 158}}=1.0458\right]$. Consequently the differ-

[1] At the Solar Observatory at Upsala by Dr. Lindholm.
[2] As A. S. the pyrheliometer No. 70 has since 1906 been in permanent use.
[3] Ångström, Anders: Met. Zschft. H. 9/10, 1919.
[4] Kimball, H. H. See this REVIEW, pp. 769–793.