The essential facts are these: The north has less sunshine than the south. The west has on the whole more sunshine than the east. The southwest is the sunniest; the northwest and northeast are the least sunny. East of the Rocky Mountains there is less difference between north and south than to the west of the continental divide. There is less contrast between north and south on the Atlantic than on the Pacific coast. The west coast has the advantage in regard to sunshine as far north as latitude 40° N.; from there northwards, the conditions are reversed. Winter is as a whole distinctly the least, and summer the most sunny season.

Many interesting comparisons suggest themselves as regards sunshine between Europe and the United States, but this consideration is not an appropriate part of the present bibliographic note. It may, however, be interesting to add that the contrast between western Europe and eastern North America was clearly emphasized by Woeikof a number of years ago.[5] He pointed out that the American coast has great advantages in respect to sunshine, especially if stations having similar temperatures and not stations in the same latitudes are considered. "Not only is the duration of sunshine longer (on the American coast) but the air is clearer, especially in the colder months. This contrast is very strikingly emphasized on the voyage from England to the United States."

A NEW INSTRUMENT FOR MEASURING SKY RADIATION.

By Dr. ANDERS ÅNGSTRÖM.

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

The idea of comparing the heat produced or lost at a certain surface by radiation with the heat produced through an electrical current in order to balance the named gain or loss of heat has shown itself most fruitful in the construction of instruments for cosmical radiation measurements. Thus after the electrical compensation pyrheliometer was constructed in 1893 by K. Ångström,[1] the same principle was used by him in 1905[2] in order to determine the so-called nocturnal radiation, and now recently by Abbot and Aldrich,[3] attempting to measure the intensity of the diffused daylight by an ingeniously modified type of the compensation pyrheliometer.

A fairly good idea having been obtained of solar radiation and its variations, the last-named problem is at present one of the most important in actinometry and certainly also in meteorology in general. At high latitudes the heat transferred to the surface of the earth through luminous radiation from the sky, viz, through diffused sun radiation, must, on the average, amount to about 40 per cent of the total heat income from sun and sky together, and in the artic regions this source of heat and light is during the winter time the most important one.

In the following, I will give a description of a new instrument for measuring luminous - sky radiation founded upon the method of electrical compensation. The instrument may be used also for measuring the radiation of the sun and it may easily, in proper combination, be used as a self-recording instrument.

The construction is schematically shown by figure 1 (A, B, and C). It is in its main features very similar to the construction of the nocturnal radiation actinometer (the pyrgeometer). The bright strips of the pyrgeometer are, however, here replaced by strips that first are blackened with platinum black and afterwards covered with magnesium oxide to proper thickness. *aa* and *bb* in figure 1 (A and C) show the white and black strips, respectively, mounted on a hard-rubber frame in the end of a nickel-plated tube. Thermo-electric junctions are provided at the back of the strips, but electrically insulated from them. These junctions may be connected

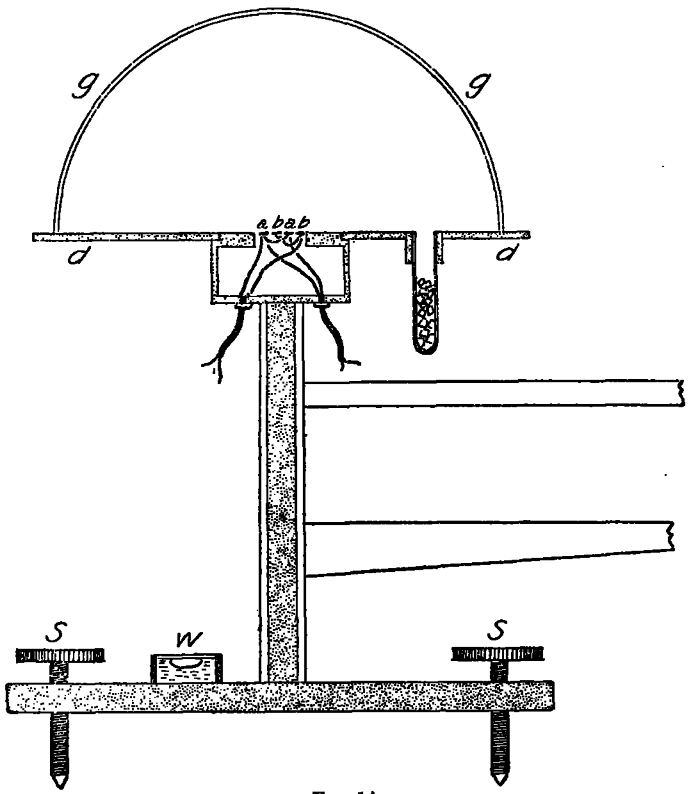

FIG. 1A.

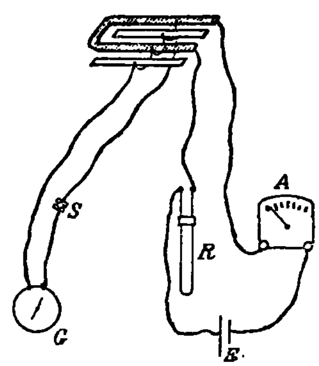

Fig. 1B

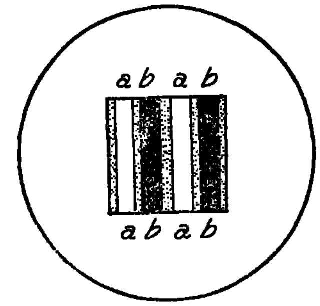

FIG. 1C.

in a circuit that also includes a delicate galvanometer G (fig. 1 B). To the tube and in the same plane with the strips is attached a circular metal disk *dd*, which acts as a support for the hemispherical glass screen *gg*, covering the strips, the purpose of which will be explained below. The metal disk is covered on its upper side by white paper, which is a better reflector for short wave radiation than the bright metal. On the supporting metal disk can also be placed a cylindrical metal cover in order to exclude the instrument from radiation from sun and sky. Through the water-level *w* and the two leveling screws *s* the hori-

[5] A. Woeikof: "Die Klimate der Erde" Jena, 1887, Part II, p. 45.
[1] K. Ångström: Nova Acta Upsal., 1893.
[2] K. Ångström: Nova Acta Upsal., 1905.
[3] Abbott and Aldrich: Smithsonian Misc. Coll., 66, Nos. 7 and 11.

zontal position of the strips can be controlled. By means of a simple device, whose construction is clear from figure 2, the sun may be screened off. The distance of the circular screen from the center of the strips is 40 cm., its diameter about 5 cm.

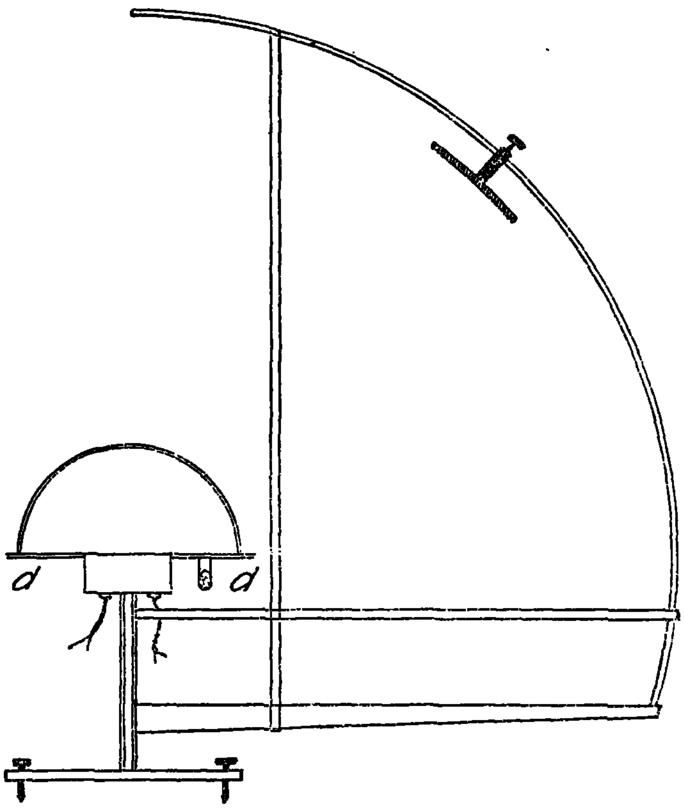

Fig. 2.

If the cover is removed and the instrument exposed to the radiation from the sun or the day sky, the black strips will absorb more heat than the white ones and consequently a temperature difference will arise between the thermo-junctions at their backs, producing a deflection of the galvanometer from its zero position. In order to regain the zero, we may send an electric current through the white strips. The current is conveniently obtained by two or three dry cells, is regulated by the slide resistance R and measured on the millameter A. We may investigate whether the radiation, R, may not, at equal temperature of the strips, be determined from the equation:

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

where i is the current in amperes and c may be expected to be a constant for the instrument.

Suppose the black strips to absorb the fraction α, the white strips to absorb the fraction β of the incident radiation. When the white strips are heated to the same temperature as the black strips we have:

$$\alpha\, R = \beta\, R + \frac{w\, i^2}{4.19}$$

which gives:

$$R = \frac{w}{4.19\ (\alpha - \beta)\ i^2} \qquad (2)$$

The difficulty in the construction of instruments for measuring the intensity of a radiation made up of several different wave lengths, lies chiefly in the selection of surfaces whose effective absorption power remains constant when changes occur in the quality of the incident radiation. If the intensity of the radiation is the same in two cases, we wish the indications of the instrument to be the same also, independent of an eventual change in the relative intensity of the various wave lengths constituting the radiation. Strictly, this is only the case when the absorption of the surface is the same for all wave lengths constituting the radiation to be measured. Some experiments which will be described below indicate that practically both the platinum black (which is well known) and the magnesium oxide fulfill this condition in the case of the sky radiation.

When we intend to measure the luminous sky radiation separately, we must take precautions to exclude the heat radiation exchanged partly between the surface and the atmosphere and partly radiated by the surface directly out to space.

This radiation is of long wave length. Its maximum of intensity lies at about 10μ, but its intensity is negligible at wave lengths shorter than 3μ. On the other hand, the luminous sky radiation has its maximum of intensity at the blue end of the spectrum, its intensity being negligible for wave lengths longer than about 2μ.

I have tried to exclude the dark radiation from influencing the indications of the instrument in a twofold way. First it may be conceived from Coblentz's[4] measurements that the magnesium oxide, though having a high and almost constant power of diffuse reflection for the short and visible waves constituting the luminous sky radiation, has a very low reflecting power and consequently a high radiation and absorption power for waves longer than 4μ. The reflecting power at 8.8μ near where the effective heat radiation has its maximum, is in fact according to Coblentz[5] only 2.5 per cent and almost exactly the same as that of platinum black (about 2 per cent). The black and white strips radiate consequently almost equally for the dark waves, which implies that these waves do not influence the temperature equilibrium between the strips or the readings of the instrument. It then is to be expected that there ought not to be any appreciable deflection of the galvanometer, when the instrument is exposed without the glass cover to the nocturnal radiation. In fact, the deflection corresponding to a nocturnal radiation of about 0.18 gm. cal. cm^2. min. was found to be less than 5 mm. against 60 mm. for the same luminous radiation. In order to cut out entirely the long-wave radiation and at the same time protect the strips against air currents the strips are covered by the hemispherical glass cover referred to above, which lets pass freely the short waves but screens off the waves longer than about 3μ. No appreciable deflection could be detected when the glass-covered instrument was exposed to the nocturnal radiation. The heating or cooling of the glass is hereby of practically no consequence, while the strips are affected almost equally by the dark radiation. This property of equal absorbing power for dark rays gives the instrument a superiority over the Callendar instrument, in which the difference in temperature between bright and blackened metal surfaces is taken as a measure of the radiation, and also over the Abbot and Aldrich pyranometer, where the strips are equally affected by all waves. In both these instruments the heating or cooling of the glass cover must necessarily give rise to a superposed long-wave radiation liable to introduce errors in the result.

[4] Coblentz, W. W.: Bulletin of the Bureau of Standards, 9, 1913.
[5] Loc. cit.

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:

$$R = c\,i^2 \tag{1}$$

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.