of the effect of radiation from the outer side of the cylinder and the covers.

In the presence of solar radiation the pyranometer, as it is generally used, is shaded from direct rays of the sun by a small round screen (E), moving on a support (F).

For the measurement of radiation according to zones this pyranometer was applied by me as a relative apparatus together with the Schleifengalvanometer of C. Zeiss, G. With this galvanometer the whole process of measuring the radiation by zones 10° in width, the determination of radiation from the whole sky and also the verification of the position of the zero of the galvanometer before and after a series of observations, could be effected in three to four minutes. The advantage of the Zeiss galvanometer is that, by means of a turning over of the box 180°, its sensibility can be several times increased. For instance, my Ångström pyranometer No. 29 in connection with the Zeiss galvanometer in normal position gave for one division of the galvanometer the value of 0.0081 calorie; whereas with the same glavanometer with the box overturned, it gave 0.0025 calorie; which is especially valuable for observations during an expedition; and my experience enables me to heartily recommend the use of this galvanometer together with the Ångström pyranometer for expedition work.

As has been stated, measurement of radiation by zones can be effected for the whole sky in three to four minutes; the work has necessarily to be completed in a short interval of time, in order that the radiation of the vault shall not change materially during the measurement. In most cases the change is not material within so short a space of time, except in rare cases of an exceptionally rapid drift of clouds, when the radiation is apt to change considerably within a few minutes; then measurements of radiation according to zones ought not to be made.

I give here, as an example, four lines of measurements of radiation according to zones—two regarding a sky free of cloud and two for a sky covered with a dense sheet of cloud.

TABLE 1.—*Distribution of diffused radiation of the vaulted sky according to zones of a clear (entirely free of cloud) and an overcast sky*

Hours of observations	9₊	h⊙	A	0°–10°	10°–20°	20°–30°	30°–40°	40°–50°	50°–60°	60°–70°	70°–80°	80°–90°
Sky free of cloud:	*cal.*	°	*P. ct.*									
Sept. 22, 1928, 9h. 17m	0.080	26.6	100	5.3	12.2	16.2	17.7	16.5	13.7	9.3	5.6	3.1
Sept. 19, 1928, 10h. 23 m	.068	18.4	100	7.6	15.0	16.9	16.4	13.2	12.8	9.5	6.1	2.5
Cloudiness (10 SCu):												
Oct. 21, 1928, 12h. 55m	.084	18.2	100	3.1	5.6	10.8	15.0	16.5	16.2	18.3	10.2	4.2
Dec. 12, 1928, 11h. 33m	.048	7.1	100	4.2	5.3	10.6	13.2	12.7	15.9	18.5	13.8	5.8

Explanation to the table:
- 9_+. Diffused radiation of the whole vault on a cm². of horizontal surface in 1 minute in gr. cal.
- h⊙ Altitude of the sun at the middle moment of observation.
- A. Radiation of the whole vault (9.) taken for 100 per cent.
- 0°-10°, 10°-20°, etc., to 80°-90°. Radiation of respective zones of the vaulted sky; from the horizon to the height of 10° and so on up to 80° and from 80° height to the zenith—in per cent of the total radiation of the vault.

In Figure 2 the values of the table are given graphically and show that the distribution of radiation over the vault for a sky free of cloud differs from that regarding an overcast sky. In the first case the maximum falls on the zone 30°–40° and in the second on the zone 60°–70°. Besides, in the presence of a clear sky the zone adjacent to the horizon radiates more than the zone round the zenith, whereas the sky being overcast the case proves vice versa. After C. Abbot, H. Kimball, W. Dines, and C. Dorno's investigations, this is generally known, and I only want to show that by means of a very simple method here exposed it is possible to obtain the same results which are generally attained by more intricate procedures.

The exposed method allows an organization of systematic observation on the radiation of the several zones of the vaulted sky. The results obtained supply many valuable data regarding the effect of various meteorological elements and topographical features on the diffused radiation, as well as its dependence upon the height of the sun over the horizon.

Series of these observations may prove very valuable for health resorts and also for agricultural purposes (e. g., for the study of the effect on growing vegetation of the shading of the lower position of the vaulted sky in woodland, meadows, mountain valleys, etc.).

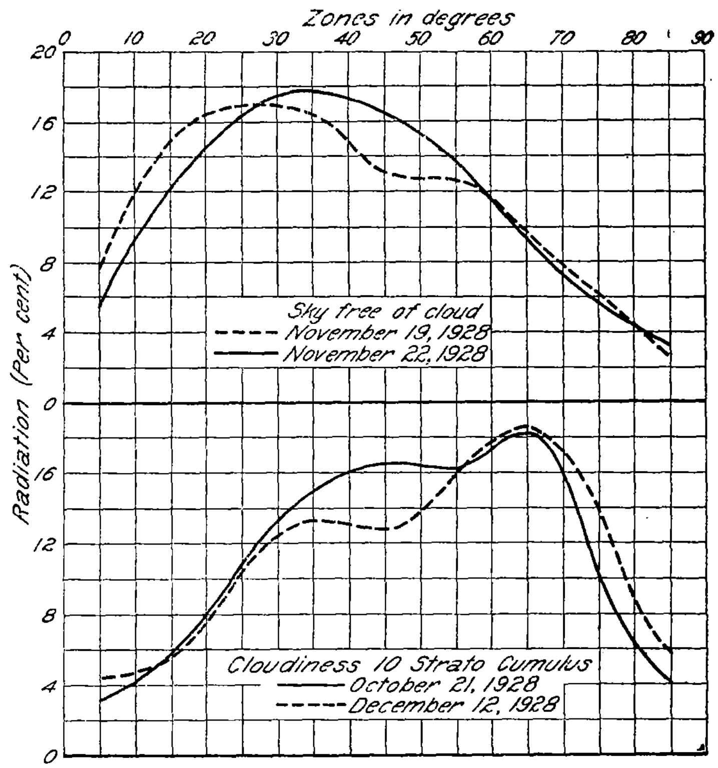

FIGURE 2.—Distribution of diffused radiation of the vaulted sky according to zones

DISCUSSION

By HERBERT H. KIMBALL

Professor Kalitin has pointed out a simple way to measure the intensity of the solar radiation received diffusely from the sky with apparatus easily obtainable. A method similar in principle has been employed by the Astrophysical Observatory at the Smithsonian Institution in measuring radiation from horizontal sky zones 30° in width; also from a ring 60° in diameter concentric with the sun, and from similar areas of equal dimensions and altitude located 60°, 120°, and 180°, respectively, from the sun.[1] The objection to these methods is that since the receiving surface of the pyrheliometric device employed has definite dimensions, different parts of it will be exposed to different sky zones. The smaller the dimensions of this receiving surface the less will be the

[1] Moore, A. F., and Abbot, L. H. 1920. The Brightness of the Sky. Smithsonian Miscellaneous Collections, vol 71, No. 4.

difference in the location of the zones measured. The resulting error will be inconsequential except when a boundary of a zone is in close proximity to the sun.

Equally as important as measurements of the relative intensity of diffuse radiation from the sun in horizontal sky zones are measurements of this intensity with reference to the sun's position, as was done by the Astrophysical Observatory, Smithsonian Institution,[1] and also photometrically by Dorno,[2] by Kimball and Hand,[3] and by others. In fact, a pyranometric measurement of the brightness of the sky in a restricted zone about the sun is an important factor in the *short method* of determining the solar constant now generally employed by the Smithsonian Institution.[4]

Our thanks are due to Professor Kalitin for calling attention to the importance of measurements that give the intensity of diffuse solar radiation received from different sky zones, which is dependent not alone upon the proximity to the sun but also upon the character of the ground surface over which the measurement is made (vegetation, sand, snow, water, etc.), and upon the water-vapor and dust content of the atmosphere.

[1] Moore, A. F., and Abbot, L. H. 1920. The Brightness of the Sky. Smithsonian Miscellaneous Collections, vol. 71, No. 4.

[2] Dorno, C. 1919. Himmelshelligkeit, Himmelspolarisation und Sonnenintensität in Davos, 1911 bis 1918. Veroff. des Preus. Met. Inst., No. 303, Abh. Band VI.

[3] Kimball, Herbert H., and Hand, Irving F. 1921: Sky-brightness and daylight illumination measurements. Monthly Weather Review, 49: 481. 1922: Daylight illumination on horizontal, vertical, and sloping surfaces. Monthly Weather Review, 50: 615.

[4] Abbot, C. G. 1919: Measurements of the solar constant of radiation at Calama, Chile. Monthly Weather Review, 47 :580. Abbot, C. G., and others. 1922: Use of the pyranometer in the measurement of the solar constant. Annals of the Astrophysica Observatory, 4: 79.

DORNO ON DAILY, YEARLY, AND SECULAR VARIATIONS OF THE SOLAR RADIATION AT DAVOS [1]

551.590.2

[Report made at the First International Conference on Light, Lausanne-Leysin, September 10-13, 1928]

By H. H. KIMBALL

In the introduction the following are enumerated as factors affecting quantitatively and qualitatively the amount of solar radiation and its variations.

First. Astrophysical and astronomical, which include—

(*a*) Solar variability;

(*b*) Earth's solar distance; and

(*c*) The astronomically determined length of day.

Second. Geographical and topographical, which include—

(*d*) Hours the sun is above the horizon (possible hours of sunshine), which is determined by the solar declination and the latitude of the place of observation.

(*e*) Topography: High mountains may cut off rays of sun while it is still above the horizon.

(*f*) Altitude: Since increase in height above sea level decreases the depth of atmosphere above the station, and also its water-vapor and dust content, and thereby decreases the atmospheric depletion of solar radiation.

(*g*) Character of the ground surface: Water, land (bare or covered with vegetation and kind of vegetation), snow, etc.

(*h*) Proximity of active volcanoes.

Third. Geophysical:

(*i*) Diffusion and absorption by the permanent gases, and by the ozone layer at an altitude of about 45 km., as well as through cosmical dust. The ozone layer, only 3 mm. thick under normal pressure, completely absorbs all radiation of shorter wave length than $290\mu\mu$.

(*j*) Fine cosmical dust and condensation products of various kinds, for the most part discharged by cathode and corpuscular rays of the sun, and which the northern lights (*aurora borealis*) reveal to us, must be present at great heights to a greater or less extent, depleting the solar rays to a variable degree.

Fourth. Meteorological—that is to say, the weather influences, extending to the upper cloud limit, or to about 10 to 12 km. of the 600 to 700 km. depth of the atmosphere:

(*k*) Principally determined by water in the atmosphere in gaseous (water vapor), liquid (water droplets), or solid (snow crystals) form. The invisible water vapor acts strongly to deplete the incoming radiation, partly through absorption of red and infra-red rays, partly through scattering, like other gas molecules inversely proportional to the fourth power of the wave length, or in connection with dust particles on which it collects, inversely as the square of the wave length.

On account of the great number and variety of factors influencing the spectral distribution and the intensity of solar radiation, the radiation climate of a place can not be accurately stated without radiation measurements and registration.

COMPILATION AND SCOPE OF EXISTING MATERIAL

With continuous measurements of the intensity of the total solar radiation covering 20 years, short gaps excepted, Davos has the longest record of any mountain observatory, and there is an older record at only a few places on the plains. The measurements were made partly with an Ångström compensation pyrheliometer and partly with secondary instruments controlled through comparison with the standard type. Continuous photographic records have been maintained since 1921 by means of the Davos pyrheliograph. The readings on the Ångström scale are reduced to the Smithsonian scale of 1913 by multiplying by 1.035.

Summaries of the measurements are given in both graphical and tabular form. Thus, in Table 1 are given hourly mean values (apparent time) of the intensity of solar radiation at normal incidence for each month of the year, expressed in gram calories per minute per square centimeter. The maximum midday mean is 1.495 in April, and the minimum, 1.354 in December, a range of 9.4 per cent. The maximum hourly mean is 1.516 at 1 p. m. in April and the minimum, 1.054 at 6 p. m. in June, a range of about 30 per cent. The low water-vapor content of the atmosphere in the spring as compared with the fall months, is the principal cause of the spring maximum of solar radiation intensity. Table 2, which gives annual means with the sun at altitude 30°, shows a maximum of 1.344 in 1921 and a minimum of 1.272 in 1925, with an annual average of 1.312. The corresponding annual average given by me for the years 1912–18 except that the monthly means were reduced to mean solar distance of the earth, is 1.35.[2]

[1] Tägliche, jährliche und säkulare Schwankungen der Sonnenstrahlung in Davos. (32 pp., 8 tables, 6 figs.) L'Expansion Scientifique Francaise. Paris, 1928.

[2] Kimball, Herbert H. 1927. Measurements of solar radiation intensity and determinations of its depletion by the atmosphere, with bibliography of pyrheliometric observations. Monthly Weather Review, 55: 161.