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PROGRESS IN RADIATION MEASURMENTS.

By C. DORNO.

[Davos, Switzerland, August, 1922.]

SYNOPSIS.

The author discusses apparatus that has been employed at the Davos Physical-Meteorological Observatory to measure the total solar radiation received at the surface of the earth, the intensity of radiation received from restricted regions of the solar spectrum, the intensity of irradiation, or outgoing nocturnal radiation from a black body, and also the radiation received at the earth's surface from the atmosphere. Especial attention is given to registering apparatus, principally of the photographic type.

A thermopile for measuring the total radiation, potassium and cadmium cells for measuring the radiation from the visible and the ultra-violet regions of the solar spectrum, and Ångström's tulipan for measuring nocturnal radiation find favor with the author.

In a brief summary of the Davos measurements it is shown that if we take into account the albedo of snow in winter and of the ground surface in summer, throughout the year "Hardly a third of the incoming radiation has contributed to the heating of the air and the melting [of snow or ice] and evaporation of moisture."

The results of recent medical researches are cited to show the value of the measurements of radiation intensity in the ultra-violet region of the solar spectrum.—H. H. K.

From its beginning in 1907 the Davos Physical-Meteorological Observatory has been endeavoring to develop reliable methods of registering sun and sky radiation, both as to their total intensity and also the intensity of the more important regions of the spectrum.

The author induced Carl Zeiss in Jena to construct for him a permanent spectrograph for ultra-violet radiation. This instrument was described in 1911.[1] Its chief object is to fix the variations in the extension of the sun's ultra-violet spectrum with the time of day and season. Quite lately the tables given (*l. c.*) have met with an unexpected and keen interest, since Hausser and Vahle [2] have proved by their very careful researches that the pigment-forming power properly belongs to a very small portion of the spectrum with a sharply pronounced maximum between the lines 0.302 and 0.297μ, from which the effect upon the epidermis sensibility falls rapidly on both sides (the research has not been extended to the mucous membrane). In *Strahlentherapie*, Band XIV, Heft 1, the author has stated the interesting biological and evolutional conclusions this result may lead to. It is of special interest to medicine, especially to the therapy of tuberculosis of the lungs, since years ago Rollier and others advanced the thesis that healing result and pigmenting power are proportional.

In this REVIEW [3] a method of registering local atmospheric clearness has been described; that is to say, the physiological action of sun and sky on the human eye is measured in terms of its effect on the horizontal plane by the photoelectric method, by means of a highly evacuated potassium cell, at a low potential (2 to 4 volts) under milk-glass and filter (Schott F 5899). This is a very reliable and easy mode of registering radiation for a spectrum region of the greatest practical importance. In the same paper the author has given data to prove that under conditions of high altitude the nocturnal effective radiation may be registered with sufficient correctness by means of Ångström's tulipan,[4] which is based on the overdistillation of ether. Comparisons between the records of Ångström's tulipan and the pyrgeometer are being continued. The indications of the former are in error only if the greatest possible condensation for Davos occurs; then they are about 15 per cent too high; that is to say, only during the time of actual condensation, not in the nocturnal mean. Therefore corrections are generally unnecessary. Farther on, this mode of registry of radiation will be more fully treated. There is also mentioned a method of registry of the nocturnal effective radiation by means of the pyrgeometer, the compensation being eliminated, by photographic indication of the oscillation of a sensitive galvanometer. This method is not to be used, except on perfectly calm nights in midwinter, since the faintest breath of air is also recorded

The chief aim in these endeavors must be the construction of a reliable pyrheliograph for the purpose of registering the solar radiation in absolute heat units or calories. The author has sketched in rough outline a pyrheliograph which combines the principles on which Michelson's actinometer and Ångström's pyrheliometer are based. These outlines were elaborated in detail by Dr. Rud. Thilenius in Darmstadt, and the copper body and the thermocouple were constructed by him. The firm of A. Pfeiffer, in Wetzlar, undertook the construction of the other parts of the instrument. (See frontispiece.)

Registering sun intensity by means of a thermo element seems very simple to an outsider, but whoever is acquainted with the historical development of the pyrheliometer remembers that for a whole century the most prominent scientific men have been occupied with the problem of how to keep off the radiation influence of the surroundings, when making radiation measurements, before they were satisfactorily solved. In the present case—as with Michelson's actinometer—the result has been attained by putting the sensitive thermocouple in a small camera of a massive cylindrical copper body of 3 kg. weight, whose large capacity keeps the caloric variations of the surroundings sufficiently damped, and whose great transmissibility brings about the temperature compensation around the small camera very rapidly. Care is taken that in the forepart of the camera plenty of reflection leads the last traces of stray rays back to the intercepting surface. The back of the camera has been carefully blackened in order to absorb all the rays that may have pierced through from the front. The cylindrical camera is 8 mm. in diameter and 23.92 mm. long; the thermocouple is exactly centered and stands symmetrical to the declination axis. It is 12.18 mm. long and consists of 18 elements of constantan copper with an intercepting surface of 30 mm. The latter is put slightly extrafocal (2.8 mm.) to the focal plane of a quartz lens of 20 mm. opening and 86 mm. focal distance which therefore shows in the focal plane objects of 1° angular extension 1.5 mm. in size. Owing to five diaphragms which can be put before the lens about $\frac{1}{1}$, $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$ of the incoming intensity may be utilized, while a brightly polished shelter protects the copper body from insolation. The in-radiating sun and sky zone may, at will, be limited to 8.4 or 12.8 or 47. 8 arc-minutes from the limb of the sun by three exchangeable diaphragms lying in the focal plane. For permanent registration the front diaphragm of 7.06 mm. diameter and

[1] *Studie über Licht und Luft des Hochgebirges*, Vieweg, 1911.
[2] *Strahlentherapie*, Band XIII, Heft 1, Seite 41 ff., Urban & Schwarzenberg, Berlin.
[3] MO. WEATHER REV., June, 1920, 48: 348-351.
[4] *Nova acta Regiae Societatis Scientiarum Upsaliensis*, Ser. IV, vol. 2, Nr. 8, 1910.

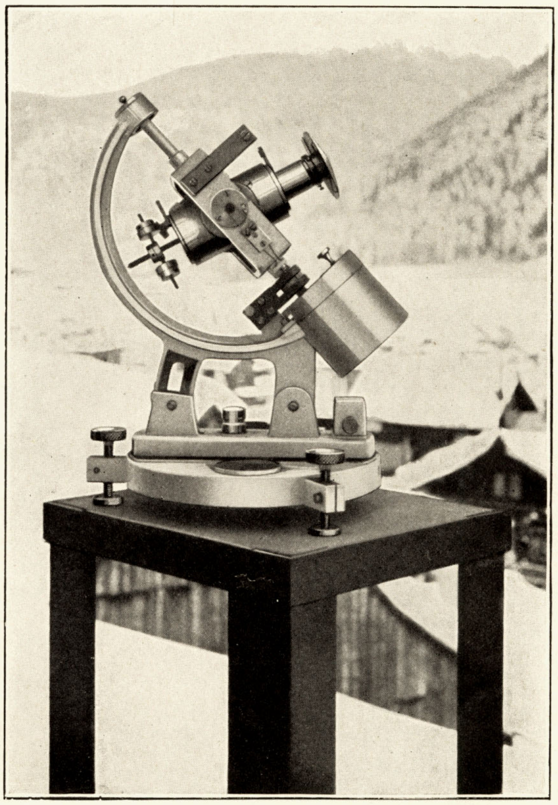

FIG. 1.—Pyrheliograph. (See p. 516.)

the largest back diaphragm are used, which lets in a sky zone of about three-fourths degree of arc. Small deviations in the day run are inevitable, partly on account of the variability of the solar declination during the day and partly because the mounting of the instrument, which is attached on the roof of the house, does not possess astronomical fixity; but the chief reason is the slight variations of the clock due to the great variations of temperature. With this arrangement the galvanometer readings remain unchanged even when the diopter image deviates half its diameter from its exact centering. The temperature developing inside the copper part could be controlled by means of an added thermometer. Even under extreme conditions it did not nearly attain the critical temperature of 50° C. at which the shellac of the thermocouple might have softened. Under the stated conditions, the thermocouple indicates at full insolation about 0.546 millivolt, so we were obliged to put in a resistance of 2,000 Ω before the Hartmann & Braun mirror galvanometer of 1.16×10^{-9} of sensitiveness, whose resistances was 1,000 Ω.

When the sun is shining brightly the registered readings vary, according to the solar altitude, between 135 and 60 mm. (1 mm.=0.01174 cal.), an hour interval corresponds to 20 mm. width. Owing to the slight heat capacity of the thermocouple which, in spite of its minuteness, can not be made to disappear entirely, there exists a somewhat greater inertia of the galvanometer, which amounts to that observed with the registering by means of Ångström's pyranometer. During the galvanometer's period (hardly 10 seconds) 63 per cent of the incoming intensity may be registered. The rise progresses in the form of a steep exponential curve; but the last seventh follows slowly in about 1½ minutes. In permanent registry there results automatically a slight compensation of the curve which, however, is hardly noticeable with the scale used.

The maxima, which must show more distinctly with permanent registering than with single measurements, were nevertheless lower during the registering period (October, 1921, to June, 1922) than the absolute maximum. For 11 years (1910–1921) since March 5, 1910, the latter has been 1.575 (Smithsonian Scale Revised, 1913) and was only surpassed May 6, 1921, after a snowfall with 1.587 at 55° solar altitude.

During the registering period the caloric sums of cloudless days have been recorded 1.8 per cent higher than those derived from single measurements in the years 1909 and 1910.

A comparison for all days between the number of registered calories by the pyrheliograph and the number of calories derived from registrations of Campbell-Stokes heliograph (sunshine duration times number of cloudiness) indicates 3½ per cent higher registered values.

Until the end of December the values were abnormally high. From the beginning of January, however, they were below the normal height. An optical disturbance was not recorded—except between May 24 and June 9, perhaps. The question arises whether this optical disturbance, which occurs every year at this epoch of the calendar, is not an optical indication of the approach of the well-known return of cold in June. In a paper in the *Meteorologische Zeitschrift*, which treats more fully of these results, the optical disturbances during and after the important aurora in May, 1921, and during the time of greater solar activity at the end of June, July, and August, 1921, are enlarged upon.

The frontispiece shows the instrument from the side view in the place where it is set up. The polar axis rests with globe-shaped pivots in the cylindric layers of a latitude arc of +-shaped cross section, which is adjustable in the limits 35° and 65° by means of a clamp at the edge. The lower part forms a console. This carries (1) the clockwork with the minute dial and (2) the springs of copper, which are insulated with slate and whose places of contact are plated with 0.2 mm. of fine gold. The rings, also, which are borne by an ivory ring, laid over the lower end of the polar axis, are of electrolytic copper with 0.2 mm. plating of fine gold; so the thermoelectric effects remain extremely minute. The conducting wires of the column are led through the hollow axis pivot (visible in the figure) of the declination axis, and joined to the gliding rings over copper transmission fixed to the frame part of the polar axis. On the other side of the declination axis is a volute wheel with 360 cogs and degree scale on the front surface, into which a tangent screw encroaches for the fine adjustment in declination. Its drum scale indicates 1′. Waterproof covered azimuth-correction screws, whose full rotation produces 30′ azimuth change, permit the full adjustment in the meridian. A lens diopter permanently controls in the easiest manner the correct adjustment of the axis of the tube parallel to the radiation, a number of counterweights regulate the compensation of the masses, so the clockwork remains uninfluenced in all the different positions of the copper part. The copper part consists of a right and a left half; they are joined by a front and a back centering cover and by three strong screws passing across. When these are loosened, the small camera inside, which contains the thermocouple is accessible. The lens tube (to be seen on the cut) with screen, front and rear diaphragms and quartz lens is carefully put in the copper part by means of a cone and is kept in the front centering cover by hinges and pressed into the copper part to the complete contact of the surface. Doctor Thilenius will soon publish a minute description of the pyrheliograph in the *Zeitschrift für Instrumentenkunde*.

Owing to the skill of Doctor Thilenius a still smaller miniature thermocouple of 12 elements of special alloys has been constructed, which, when fully exposed to the sun, gives about 4 millivolt, a power which would enable us to replace the photographic by a mechanical registration.

The instrument, which has been in permanent operation since October, 1921, i. e. now more than 10 months, has stood all tests. Comparisons with Ångström's compensation pyrheliometer have given the relation 1 mm. = 0.01174 cal., the deviations from this relation keep within one unit of the fourth decimal and are in nowise systematic with one exception; when the sun is low and the sky not quite clear, the relation always rises to 4 per cent. The reason for this is not to be found in a different reaction to the irradiating intensity, but in variations of the intensity. As has been said above, the pyrheliograph permits only a sky sector of ¾° of the edge of the sun to irradiate, the Ångström-Michelson silver disk instrument, however, a much larger one of about 5°. Thus the pyrheliograph gives the more exact (the smaller) readings. This question having been treated elsewhere [5], we shall not enter upon it here. Of the results realized we shall only mention the following:

If monochromatic filters are placed before the pyrheliograph, the intensity of separate parts of the spectrum may theoretically also be registered. But two misgivings exist: (1) The available filters are not sufficiently monochromatic and especially not sufficiently examined as to their transmissibility in the ultra-red spectrum; (2) owing to the absorption of the incoming radiation the filter itself becomes the source of long-wave heat radiation, which vitiates the measured results. This latter danger may be met by leaving a sufficient air layer between the filter and the opening; the former can only be avoided in the red spectrum. The otherwise excellent Wratton-gelatine filters must be transparent to ultra-red rays, else they could not, contrary to proved laws, record at sunrise smaller intensity increase in blue-violet than in green, and in green smaller than in red. Red glass Schott F–4512 has proved highly monochromatic and seems to be opaque to ultra-red. After deducting the absorption of the 2 mm. filter, there resulted for the mean of the year the following true red portions of the total intensity as a function of the air mass (S):

S	Red / White
1.1	0.602
1.3	0.609
1.5	0.617
2.0	0.636
2.5	0.654
3.0	0.673
3.5	0.692
4.0	0.711
5.0	0.748

[5] *Abhandlungen des Preussischen Meteorologischen Instituts*, Band VI, 1919, p. 61.

An annual variation in the red portion is clearly to be observed. It rises at first rapidly, then slower from October till March; in April and May it diminishes but slightly; June, July, and August show changing values, for the most part below the spring values, but sometimes surpassing them by far. In the atmosphere of autumn, rich in water vapor, the red portion falls again from September to the October minimum. Parallel measurements made by this method at Davos (1,600 m.) and Potsdam (100 m.) show that in the clear month of October the red portion of the solar spectrum at Davos at 20° solar altitude is 7 per cent, and at 30° solar altitude is 4 per cent, smaller than at Potsdam.

In this periodical[6] A. Ångström and the author gave an account of the pyranometer, constructed by Ångström, its slight imperfections, its appropriateness for registering with compensation eliminated, and the first results realized at Davos in November and December, 1920. The registering has been carried on during an entire year (November, 1920, to October, 1921). Another slight imperfection of the instrument has been found: When permanently used the white magnesium oxide loses its delicate freshness; minute quantities of the light powder detach themselves under the influence of heat and artificial dryness, and disappear without visible traces when the instrument is moved into a room to be protected during the night or for other measurements. A slight hue of green then lies on the white. According to the diminution of the reflective power the constant of the instrument increases. It is difficult to re-whiten the two strips on account of their position between the black strips, besides there exists the danger that the magnesium smoke might at the same time touch the thermo elements. Therefore the author did not dare to do it himself. Rose, of Upsala, however, carried it through in May and June, and as a result registrations were secured for two decades in May and one in June. The constant, that has been permanently controlled, as was described,[7] kept satisfactorily at 12.93 from November to the middle of February; then, for the reason mentioned, it rose slowly to 16.66 on May 6. After the return from Upsala the instrument, whose strips had been newly whitened, recorded the value 12.90, but in the heat of summer and being sometimes intermittently used for other purposes, it rose to 15.53 at the end of July and at the end of October to 20.50. This imperfection and the inconvenience of having to calculate the registered readings with changing factors in calories might be avoided, or at least be reduced to a minumum, if the instrument could be kept free from every disturbance.

The readings of the pyranometer and those of the new pyrheliograph could to some extent be compared with each other. The difference of registered solar + sky radiation, which falls on the horizontal surface, and the sky radiation alone, fixed by single measurements, must be about equal to the solar radiation falling on the normal surface times the sine of the solar altitude. The comparisons were satisfactory and proved the reliability of the readings of both instruments. The radiation of a cloudless sky on a horizontal surface may increase the direct solar radiation by 18 per cent in the brighter spring and autumn; in the summer months, with an atmosphere rich in water vapor, by 24 per cent (relative to the mean of the day totals). On clear autumn days it amounts to—

Solar altitude:	Cal.
10°	0.020
15°	0.038
21°	0.053
25°	0.075
35°	0.080
40°	0.075
45°	0.079

Bright cumuli raise it to 20 per cent, even if they cover only one-tenth of the sky; bright stratus at solar intensity S_{2-3} raise it to the 3 or 4 fold value. As highest value of sky radiation was found 0.406 cal. at 44° solar altitude, the sky being bluish white with föhn. On cloudless days the absolute maximum of sun + sky radiation was 2,165 (in June after a snowfall at 66° solar altitude). Only once, on September 5, with clear sunshine and clouds combined, has it been surpassed—by the extraordinarliy high value 2.491, when the whole sky was covered with light gray nimbus clouds which the sun pierced suddenly. Of course the general action of clouds lessens radiation. In the yearly mean the normal values lose 21 per cent through it; in the three winter months only 19 per cent, in the three summer months, however, 27 per cent.

During the same period (November, 1920, to October, 1921) the registering of nocturnal radiation has been carried on by means of the tulipan during all the favorable nights, beginning and ending with a solar depression of 6°. The very considerable material obtained enabled the author to make the sums of the effective radiation and of the radiation of the atmosphere derived from it, and to examine into the influence of cloudiness, as well to its degree as to its kind.

TABLE 1.—*Nocturnal effective radiation A and radiation of the atmosphere E.*

[Integration values of the whole night from 6° after sunset to 6° before sunrise.]

Date.	Temperature.	Abs. humidity.	*A*	*S*	*E*	E_{20}
1920.	°C.	Mm.				
Nov. 19	−5.3	0.93	0.236 (0.177)	0.420	0.184	0.264
Dec. 25	1.2	2.78	0.181 (0.172)	0.463	0.282	0.368
1921.						
Jan. 25	−4.6	2.33	0.179 (0.161)	0.425	0.246	0.349
Feb. 23	−6.6	1.47	0.215 (0.165)	0.413	0.198	0.290
Mar. 10	−2.7	1.72	0.215 (0.174)	0.437	0.222	0.307
Apr. 2	2.1	3.84	0.194 (0.162)	0.469	0.275	0.354
May 6	−3.8	2.61	0.203 (0.161)	0.430	0.227	0.319
June 26	9.9	6.74	0.185 (0.156)	0.524	0.339	0.390
July 10	9.1	6.38	0.198 (0.156)	0.518	0.320	0.373
Aug. 8	12.7	8.56	0.179 (0.151)	0.545	0.366	0.405
Sept. 13	7.0	5.85	0.200 (0.155)	0.503	0.303	0.363
Oct. 10	6.2	4.77	0.207 (0.161)	0.497	0.290	0.352

REMARKS.

Nov. 19 means night from Nov. 19 to 20.
Radiation constant = 8.184×10^{-11}.
A = Effective radiation.
S = Computed radiation of a black surface.
E = Radiation of the atmosphere.
E_{20} = Radiation of the atmosphere of 20° C.
The numbers in parentheses are Ångström's parallel values.

The table shows that on perfectly cloudless nights the effective radiation depends more on the humidity of the atmosphere than on its temperature. The radiation of

[6] Mo. WEATHER REV., vol. 49, No. 3, p. 135–138. [7] *Loc. cit.*

the atmosphere, however, depends more on the temperature. Since temperature and humidity counteract each other in their effect on the effective radiation, the yearly variation is slight, and only the clearest months of spring and autumn show high values. The yearly run of the radiation of the atmosphere, however, shows, as was to be expected, great amplitude—nearly 1 : 2 (0.184 in November and 0.366 in August) from the cold to the warm season. Compared to the effective radiation values calculated from A. Ångström's formula [8])—

$$E_{30} = K - C - 10^{-\gamma p}$$
$$K = 0.439$$
$$C = 0.158$$
$$\gamma = 0.069$$
p = vapor pressure in mm.

those found at Davos are 23 per cent higher, in perfect correspondence to A. Ångström's[9]) proportional numbers for different altitudes (0 meter, 0.44; 1,500 meters, 0.34). This results from the addition of the corresponding columns. This conformity proves once more that the atmospheric conditions of the Swiss Alps and the Californian Sierra where Ångström has collected the material for his formula are very similar.

Of 123 nights whose mean cloudiness at the beginning and at the end has been taken into account the following percentage loss could be derived for the cloudiness degrees 10 and 5, as compared with the effective radiation resulting under the same conditions of humidity and temperature when there were no clouds:

	Ci.St.	A.St.	St.Cu.	Nb.
B_{10}	30	60	80	94
B_5	16	33	45	52

If we express the relation between cloudiness and effective radiation with Ångström's formula—

$$A_m = (1km) - A_o.$$

m = degree of cloudiness (in tenths of the covered sky surface)
A_m = effective radiation at this degree of cloudiness
A_o = effective radiation with cloudless sky
k = constant
the following constant values for the different kinds of cloudiness will result:

Ci.St.	0.031
A.St.	0.063
St.Cu.	0.085
Nb.	0.099

The results of observation and calculation with other degrees of cloudiness agree satisfactorily. Compared with results of the lowlands it seems that the influence of cirri is greater in the high mountains. This is hardly to be wondered at, since they add a screen of equal thickness to a relatively thick one already existing in the valley, and to a relatively thin one at the high altitude.

Admitting that the long-wave radiation of the day sky corresponds to that of the night sky, based on C. G. Abbot's and A. Ångström's measurements during solar eclipses, the long-wave radiation of the day sky has been calculated according to Ångström's formula from absolute humidity and temperature from the three observation times for all days from twilight to twilight, of which the night total has been observed, using the well-known formula $\frac{a+2b+c.}{4}$ For the other 195 days, of which no nocturnal observations were available, the mean $\frac{a+b+c}{3}$ was used to calculate the radiation of the 24-hour day.

Of the radiation values to be expected with a cloudless sky under the same conditions of humidity and temperature the fraction resulting from the formula $A_m = (1-km)A_o$ (for the four different k values mentioned above) was taken for every kind and amount of cloudiness. In the values of the monthly radiation totals thus received the maxima are again to be found in the months known to be the clearest; the amplitude, however, is much greater, 1.6 from June to March, and cloudiness exerts a greater influence than either temperature or humidity.

Finally, the whole heat exchange by radiation has been derived from this material (1) for the effective prevailing conditions, (2) under admission of a cloudless sky.

TABLE 2.

EFFECTIVE TOTAL CHANGE OF HEAT BY RADIATION, NOVEMBER, 1920, TO OCTOBER, 1921.

Month.	Inradiated.	Outradiated.	Gain (+), loss (−).
1920.	*cal.*	*cal.*	
November	5,730	5,925	−195
December	4,376	4,641	−265
1921.			
January	4,770	3,819	+951
February	8,608	5,220	+3,388
March	14,577	6,084	+8,493
April	15,847	3,872	+11,975
May	16,671	3,904	+12,767
June	18,616	3,766	+14,850
July	19,832	4,897	+14,935
August	15,847	4,296	+11,551
September	14,037	5,152	+8,885
October	11,118	5,787	+5,331
Year	150,029	57,363	+92,666

THEORETICAL COMPUTED CHANGE OF HEAT; CLOUDLESS SKY.

Month.	Inradiated.	Outradiated.	Gain (+), loss (−).
1920.			
November	6,061	10,200	−4,139
December	5,248	8,079	−2,831
1921.			
January	6,651	7,991	−1,340
February	10,039	8,668	+1,371
March	15,661	9,596	+6,065
April	20,516	8,381	+12,135
May	23,542	9,061	+14,481
June	27,287	7,993	+19,294
July	24,620	8,839	+15,781
August	22,501	7,991	+14,510
September	15,682	8,640	+7,042
October	12,722	9,241	+3,481
Year	190,530	104,680	+85,850

The effective yearly heat exchange shows with 92.7 kilogram-calories per square centimeter a somewhat greater gain (8 per cent greater) than the theoretical one; the reason for it is this: the outgoing radiation is diminished 45 per cent and the incoming only 21 per cent by the clouds. With a continually cloudless sky the months of November to January, when the sun is lowest, would bring a considerable loss of heat through radiation, but in reality we find it only in the months of November and December, when their cloudiness is not considerable and even then not in a high degree. Altogether 38 per cent of the incoming radiation was returned and 62 per cent

[8] *Smithsonian Miscellaneous Collections*, vol. 65, No. 3, 1915.
[9] *Meteorologische Zeitschrift*, 1916, p. 534.

was retained. This calculation holds for the absolutely black surface and changes completely if we take into account the albedo of the earth's surface. If we put for the incoming radiation during the five months with snow cover (December to April) the snow absorption 0.3 (albedo[10] in the mean 0.7) and during the seven months without snow cover the mean absorption of meadow and stone 0.9 (albedo[10] meadow 0.06, gravel 0.13), while the long-wave effective radiation remains unchanged (for according to J. Maurer's measurements and from theoretical reasons the snow radiates like a black surface, and the same may be admitted of the vegetation, humus and stone cover) we get:

Incoming radiation in December-April	14,453
Outgoing radiation in December-April	23,636
Outradiated	9,183
Incoming radiation in May-November	91,666
Outgoing radiation in May-November	33,727
Inradiated	57,939
Incoming radiation in the year	106,119
Outgoing radiation in the year	57,363
Inradiated	48,756

In reference to the total incoming radiation indicated by the black surface (150,029 according to Table 2) only 32.5 per cent was retained in the year, and 67.5 per cent was given out by radiation; in summer 38.6 per cent retained and 61.4 per cent given out; in winter the whole incoming radiation besides 6 per cent more was given out. So hardly a third of the incoming radiation had contributed to the heating of the air and the melting and evaporation of the precipitation. Under the conditions of the highland valley with its thin atmospheric envelope and its five-month snow cover, two-thirds of the incoming radiation has conserved radiation energy through back radiation, and only one-third is transformed into heat—another proof for the high importance of radiation for the high-altitude climate.

It is true the albedo values taken into account are based on photometric determinations, and it still remains to be proved, whether they also hold good for other parts of the spectrum, especially the infra-red ones. According to investigations in different parts of the spectrum carried on at Davos, the albedo of newly fallen snow rises slowly but systematically from ultra-violet through blue, green, to yellow and even to red. It is not improbable, that the albedo of meadow and stone would also increase toward the infra-red end of the spectrum; that would give the result still more point. However, the difference of the albedo values is only an apparent one, produced by the heterogeneity of the light sources acting simultaneously. The solar radiation, which is rich in yellow and whose incidence is determined, is more intensively reflected from the surface of the ice crystals than the blue-sky radiation whose incidence is diffused.

PERMANENT REGISTERING OF THE ULTRA-VIOLET SOLAR RADIATION, NOVEMBER, 1920, TO JUNE, 1922.

Permanent registration of ultra-violet radition offers to meteorological optics the fairest prospect of continuous data relative to the degree of optical purity of the atmosphere; for its variations may best be noticed in the short-wave spectrum. One may especially expect to obtain evidence on the variations of the amount of ozone in the high atmosphere—an element which surely is very important—and on a parallelism of the variations of the optical transmissibility with the rotation period and with single revolutions of the sun.

A parallactically mounted cadmium cell, supplied with a thin argon filling, and made to follow the sun by means of a clockwork, was exposed under a mat uviolglass[11] at a distance of 112 mm. therefrom on which an image of the sun of 10 mm. diameter was projected by a quartz lens of 53 mm. diameter. The uviolglass disc having 30 mm. diameter, only ½° sky zone round the sun radiated in upon the cell. The resulting photocurrent was conducted through a mirror galvanometer of 8.55×10^{-11} at 1-m. scale distance and was photographically registered. Günther & Tegetmeyer, Braunschweig, have constructed the instrument with their wonted precision, and it is similar to the well-known electric photometer for visible light, made in the same workshop. The uviolglass is only employed in order to spare the cell and especially to protect it from too great heat. In the latter respect the precaution may have been exaggerated, for cadmium melts in vacuum only at 320° C. under a simultaneous vapor pressure of 0.001 mm., which, however, is below that of the argon-filled cell; but in the former respect the precaution was absolutely necessary. For, although the uviolglass was used, the following phenomenon could be observed. In order to obtain sufficiently high readings an auxiliary potential of about 160 volts was necessary. With it the day curves always show a perfectly symmetrical course, whose accuracy is absolutely not to be doubted. The sensitiveness of the cell, however, decreased continually during the registering period of 1¾ year. The decrease of sensitiveness can be stated by comparison with cadmium cell II, which has not changed since 1915. The latter has been employed to make only single measurements, and its sensitiveness has been constantly controlled by a controlling cell.

During the first days, while only experiments were made and comparisons were unfortunately not yet carried on systematically, the decrease of sensitiveness was very considerable (about two-thirds of the original sensitiveness). Later on, its fall was nearly linear and continued to go slowly down, every month, so that now, after 20 months of permanent use it possesses only about half of the original sensitiveness. The reverse of an uniform measure was operated, as has been told, by reduction to the regularly collected parallel readings of cell II. Whether this decrease of sensitiveness is caused by the loading up of the glass in proximity of the anode, or by an invisible thin cadmium layer on the platin ring of the anode, or by changes of the surface, or perhaps of the gas filling, has not been investigated. A change of poles, which might have given information, has been intentionally omitted, in order not to disturb the uniformity of the series. Grounding of the positive pole, which was done three times a day, in order to fix the zero line, did not operate to change the curve line of the zero line, not even at noon after half a day's permanent irradiation. Neither was there a decrease of sensitiveness observed after a long period of fine weather, when the exposure could last for weeks, nor when after long interruption by a period of bad weather, registering could again be taken up. Registering was carried on during all undisturbed days. The considerable material, which

[10] *Abhandlungen des Preuss. Meteorolog. Inst.*, Band VI, 1919, p. 214.

[11] A technical term for a glass that transmits far into the ultra-violet.—EDITOR.

resulted, confirms anew the yearly run which has been fixed by single measurements since 1909, as follows:

With the same solar-altitude there is a minimum in midsummer, and a maximum in midwinter; months of the second half year show greater intensity than the months of the first half year; especially is autumn intensity much greater than spring intensity. The intensity rises from 8 to 340, while the sun is mounting from 10° to 65°. The transmission coefficient is 0.229 in the yearly mean in 1921, while it was 0.253 in 1916 and 0.278 in 1917. The increased observational material collected, and which has not been confined to the finest days, explains, at least to some extent, the deviation toward a diminution of the transmission coefficient. The absolute numbers are somewhat lower than in the preceding years, which, to a small extent, may be owing to the loss of radiation in the small zone surrounding the sun, which has just been mentioned. If we look at all the long series from 1915 to 1922, we have, in spite of the numerous gaps, the convincing impression that the ultra-violet solar intensity (not taking into calculation the yearly run) has, generally speaking, decreased permanently from 1915 to 1922, from 1915 to 1917 rapidly, afterwards more slowly. Only the values of the extraordinarily clear days in the latter part of autumn 1920 and 1921 are an exception. The accuracy of this result may of course be doubted. There may be objections, viz, that even the best-protected standard cell of the observatory (No. II), which was used for single measurements only, may have diminished somewhat in its sensitiveness. However, it has from time to time been controlled by cell No. I, which until the autumn 1921 was used only for controlling purposes, and no change in the relation of sensitiveness could be ascertained. Even though we were inclined to correlate the result with the sunspot period, we should have to come to the conclusion, that just in the beginning of the increased activity (spot eruption) the emitted radiation was most considerable and not at the time of the maximum size of the spots. It will need a much greater amount of material, permanently registered and collected at different places of the earth, to substantiate this result.

An influence of the rotation period could not be established with certainty during this time of slight solar activity. Cirro-stratus alone weakens even in its lightest shape the ultra-violet radiation of the sun's disc 10 per cent, while the total intensity is only decreased half as much. The ultra-violet maximum values coincide in the same season with the clearest and bluest sky; they are found after snowfall and together with foehn descending into the valley. On days with tendency to thunderstorms they do not appear, as the zinc ball photometer erroneously indicates—most probably the error is due to the humidity of the air. Also the sudden and quick jumpings, which this instrument records, do not exist in reality and may also be due to the cause just mentioned. The registering curves run undisturbed on all cloudless days. The tendency of the atmosphere to condensation shows itself very soon and very characteristically in the ultra-violet solar radiation. When cumuli arise, radiation undergoes a small loss; a greater one, however, when alto-cumuli arise. The telluric solar corona, which the author measured, described and explained in former publications [12], lessens the ultra-violet solar radiation little, if any, and the registering curve runs perfectly undisturbed. The case is different with the obtrusive, dazzling white corona, which is the first sign of tendency to condensation. Under its influence the curve is constantly slightly wavering, and it also lies somewhat below the normal level.

Besides its great advantages, accuracy and possibility of registering the galvanometric method presents also a considerable disadvantage to measurements in ultra-violet. The instrument is not transportable. The very slight photo-current, produced by the cadmium cell, needs an extremely sensitive galvanometer, that must be most carefully protected from vibrations and all influences from outside, and whose foundation must be very firm. However, a special way of employing the cadmium cell is to be advocated here, which remedies this defect. K. Kähler [13] first inaugurated this method in Kolberg. Nine months ago it was adopted here with slight changes. This electrometric method may best be called the *discharging* method in opposition to the *charging* method. The cell, which stands in connection with a Wulf electrometer, is charged up to a certain potential, whose discharging velocity under the influence of ultra-violet radiation gives the measure of intensity. In order to diminish the too great intensity, suitable diaphragms were used here. They are easily switched on in the well-known "Electric photometer for visible light." An auxiliary capacity was not needed. There existed at first strong misgivings as to whether the described application would be possible, and whether the photo-current would always remain proportional to the incident intensity, the cell used being neither evacuated nor in a state of saturation and the connection between the current and the potential at constant illumination being not given linear but by the characteristic. Innumerable comparison measurements made with the registered values galvanometrically recorded, and also those with two cells used simultaneously according to this discharging method, have proved that the method is reliable, if the following important points are considered:

(1) In the limits of the discharge the characteristic of the cell must have a linear course.

(2) In the limits of the discharge the characteristic of the electrometer must have a linear course.

(3) The positive, not the negative, pole must be charged in connection with the electrometer (in order to avoid photo effects on the electrometer).

(4) A too nearly exhausted cell must not be used—only experiences with normally argon-filled cells are at hand.

If these rules are observed, this simple mode of measurement will prove astonishingly efficient. Having only a bifilar electrometer at my disposal and being therefore unable to fix quite exactly the crossing time of a certain scale division by means of a stop watch, I adopted the following expedient: Within a large scale area, in which the characteristics of the cell and the gauge curve of the photometer run lineally, the discharge area was but approximately adhered to (with the Davos instrument between 150 and 100 volts) and the readings were taken immediately before and after the exposure, while the fibers stopped. The measure was then the following:

$$\frac{10000}{t}\left(\log\frac{V_0}{V}-\frac{V_0^1}{V^1}\right)$$

t in seconds

V_0 and V beginning and end potential with radiation

V_0^1 and V^1 beginning and end potential without radiation for the controlling of insolation.

[12] *Abhandlungen des Preussischen Meteorologischen Instituts*, Vol. V, p. 5. 1917.

[13] *Abhandlungen des Preussischen Meteorologischen Instituts*, Band VII, Nr. 2, 1920.

I multiplied by 10,000 to get easy numbers. The insolation loss always kept below 1 per cent, except at quite low solar altitude, and was generally negligible. I always made three measurements, of which the mean was taken. At constant sun their variations keep within narrow limits; they mostly amount to about 1 per cent of the mean value. Sudden jumpings like those occurring with the zinc ball photometer were not seen. The time of discharge was regulated by different large diaphragms, and nearly always varied between the limits of 12 and 25 seconds.

The method is especially fit to be used in fixing the ultra violet local clearness by switching in several mat quartz plates. The diminution of radiation, which ensues, is fatal to the galvanometric method, but in this case it is generally desirable. Further, this method has been applied to the comparison of the intensity of the quartz lamp (so much used in medicine now) and that of the sun within that ultra-violet spectrum section, which both kinds of radiation have in common. Ten different burners partly new, partly old ones were examined. The exact data were published in "Strahlentherapie," Band XIV, Heft 1 (Urban & Schwarzenberg, Berlin). The result, which will interest most here, is: The Hanauer quartz lamp, supplied with a new burner (so called *Künstliche Höhensonne*) furnishes:

At 100 cm. distance..	3.7 fold	sun intensity, in relation to Davos sun intensity at the mean of sun's altitude.
At 70 cm. distance..	6.1 fold	
At 50 cm. distance..	12.2 fold	

Some simultaneous comparison measurements, made in Chur (587 m.), Davos (1,590 m.), Schatzalp (1,860 m.), furnished the result that within these altitudes with a cloudless sky observation and calculation from transmission coefficient (the different sea levels being taken into consideration) are in good agreement, except during special weather conditions. For instance, when there is a foehn prevailing, decending far into the valley of the Rhine, while it passes above the Davos valley, then there arise above the latter light strata, recognized by the whitish blue color of the sky, in the former. However, the air is then of the highest possible transmissibility—in this case the Chur values have been considerably higher than those resulting from calculation.

INFLUENCE OF COVER CROPS ON ORCHARD TEMPERATURES.

By FLOYD D. YOUNG, Meteorologist.

[Weather Bureau Office, Los Angeles, Calif., October 1, 1922.]

Among the growers of citrus fruits in California the belief that the presence of a cover crop in a citrus grove greatly increases the frost hazard has been growing rapidly during the past few years. Several reputable citrus growers have found much more damaged fruit in portions of their groves in cover crop than in clean cultivated sections. Other growers have stated that cover crops lowered the temperature of their orchards as much as 8° during frosty nights. As a result of this belief the tendency in orchard management has been away from winter cover crops.

Cover crops are considered by agricultural specialists to be of unquestioned value in maintaining the fertility of the soil and supplying humus. In some sections of California cover crops in citrus groves are considered to be absolutely necessary on account of soil conditions. Much additional irrigation water is required to grow summer cover crops in citrus groves, and where water is scarce summer cover crops are out of the question. Unless plenty of water is available for both cover crop and trees the cover crop will compete with the trees for moisture, with resulting injury to the tree. During most winter seasons in California there is abundant rainfall and winter cover crops can be grown without irrigation.

Early in the fall of 1921 the Weather Bureau was requested by officials of the Citrus Experiment Station at Riverside, Calif., to carry out experiments to determine to what extent, if any, a cover crop lowered the temperature on a frosty night.

A number of investigators had already studied this question by the simple expedient of selecting two groves, side by side, one in cover crop and the other clean cultivation, and making temperature observations in the two on frosty nights. Several years work in investigating frost conditions in southern California had demonstrated that such methods would be open to criticism. Differences in temperature of several degrees are often found within a few hundred feet on frosty nights, on ground which to the eye appears perfectly level. This being the case, differences in temperature observed between adjoining groves may be due entirely to causes other than the presence or absence of cover crops.

The plan of operation decided upon was as follows: It was desired to obtain a 10-acre orange or lemon grove in which the cover crop had attained considerable growth early in the fall, and divide it into two 5-acre sections. Temperature stations were to be installed at about the center of these 5-acre plots, the stations to be moved about until two points were found where the temperatures were as nearly the same as possible. After it had been demonstrated that there was a consistent relation between the temperatures at the two stations, the cover crop in one of the 5-acre plots was to be plowed under, and the ground cultivated thoroughly.

It was necessary to find a grove in cover crop which was surrounded by clean cultivation for some distance on every side, or to plow up a very large section of a grove in a neighborhood where all the groves were in cover crop. This is due to the fact that if the cover crop did depress the temperature to any great extent, this cooling effect would be felt some distance away over a clean cultivated area, due to the air drift which is practically always found in this section on a frosty night.

Much difficulty was experienced in finding a suitable grove, the owner of which was willing to plow under half his cover crop about two months earlier than usual. This was to be expected, since no money was available with which to make up the grower's loss. It finally was necessary to accept the offer of a 6-acre orange grove, near Pomona, Calif., belonging to Mr. H. J. Nichols. Mr. Nichols deserve much credit for his cooperation in this work, which was carried on for the benefit of all the citrus growers in the State.

DESCRIPTION OF THE GROVE.

The grove selected lies on practically level ground. Navel orange trees, 25 years old, are set 20 feet apart, shading a consiserable portion of the ground. The soil is a sandy loam, very deep, and without gravel. The cover crop consisted of *Melilotus indica* sowed 30 pounds to the acre, and rye, 10 pounds to the acre, with a scattering of purple vetch. Toward the end of the frost season the rye stood 2½ feet high, with a heavy crop of *melilotus* ex-