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SYMPOSIUM ON RADIATION

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of the International Association
of Meteorology and Atmospheric Physics

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Radiation Symposium

OXFORD, JULY 20 - 26, 1959

A symposium on radiation in the atmosphere was held at the Clarendon Laboratory, Oxford from 20th to 26th July, 1959. It was sponsored jointly by the International Association of Meteorology and Atmospheric Physics of IUGG and the World Meteorological Organisation. Financial support was given by the International Council of Scientific Unions. The programme was arranged by the Radiation Commission of IAMAP, and meetings were held in parallel with those of the symposium arranged by the Ozone Commission.

This article summarizes the scientific proceedings of the symposium. The reports of papers are in the main shortened versions of the extended summaries provided by authors for circulation to the delegates. In a few cases however the summaries have been compiled from notes made during the meeting.

Some seventy delegates registered for the symposium; seventeen of them registered for the Ozone symposium also. It was generally agreed that the papers presented were of a high standard, unfortunately they were too numerous to allow adequate formal discussion. American universities and research institutions were well represented and there was a small but active delegation from the U.S.S.R., one of whom, Prof. K. Ya. Kondratiev, distinguished himself by reading for absent Russian authors five papers in a single session, without exceeding his allotted time.

The symposium was opened on Monday 20th July, in a joint session with the Ozone Commission. Mr. T.C. Keeley welcomed the delegates on behalf of the Clarendon Laboratory, and Prof. J. Van Mieghem (President) and Dr. K. Langlo spoke on behalf of WMO and IAMAP respectively. Prof. Dr. F. Möller, President of the Radiation Commission, and Dr. G.M.B. Dobson, President of the Ozone Commission then delivered addresses on the role of their respective disciplines in the development of meteorology.

The President's opening address

Prof. Möller, in his address, traced the history of attempts to incorporate a knowledge of radiative heat-sources and sinks into theories of the circulation of the atmosphere. He then outlined the work of his Department at Mainz on the calculation and mapping of radiative heating and cooling on a synoptic basis.

"During the last few years with four collaborators I have carried out an extensive investigation of the synoptic distribution of the radiation balance of the atmosphere on a physical basis. For 6 months of the year 1955, we have calculated the short and long wave radiation fluxes at 100 European stations, 4 months of them by use of modern electronic computers. A total of 23,000 single values have been calculated and are available. This material has been evaluated statistically in order to study the influence of single meteorological elements. Such a statistical analysis appeared to be necessary because the influence of the different elements can affect the absorption of solar radiation as well as the emission of long wave radiation, and these effects can intensify or diminish each other. The influence of a cloud cover acts with opposite sign upon the short wave and the long wave shares of the balance. An increasing cloud amount increases the absorption of solar radiation as well as the emission of terrestrial radiation in the case of low clouds, so the influence upon the radiation budget is complex and still unclear. Furthermore, there are inter-relations between the different influencing elements. The temperature is connected with the geographical latitude, the vapour content again with the temperature, the cloudiness with the vapour content and again the relation between one of these elements and the radiation balance can be disturbed by another element and the quantitative connexion has yet to be investigated. By this, the statistical investigation was made necessary although the single values had been calculated by exact methods.

(Correlation coefficients, based on 600 to 2, 000 single values, between the radiation balance and various synoptic parameters were exhibited).

The material is divided into 3 seasons and 4 latitude zones, the dependence on latitude and on the sun's declination is therefore not given by correlation coefficients but is evident from their variation. One recognises that the dependence on the water vapour content of the whole atmosphere which ought to be very clear according to our qualitative considerations is really insignificant and even has the opposite sign in winter and summer. In the same way, the influence of the temperature at the 300 mb surface and that of the dew point difference at the earth's surface are insignificant . An influence of the temperature at the surface is secured in only 2 or 3 cases in higher latitude. The connection with the rate of cloudiness N is however very distinct, but decreasing from high to low latitudes. This change reflects the transition from low stratus clouds in high latitudes to clouds in higher elevations and to taller cumulus clouds in lower latitudes, because the low clouds enlarge the radiation balance and high-reaching clouds diminish it. Also the influence of the dew point difference in 300 mb is very significant; it is affected by the emission of terrestrial radiation and in the same sense by the absorption of the solar radiation. This is no contradiction against the correlation with total water content, because the total amount of water vapour is mostly determined by the vapour content of the warm lower layers. The correlation clearly increases with decreasing latitude. The rate of cloudiness N and the humidity of the high troposphere are thus the only variables which have an influence worth mentioning. If one looks at the partial correlations, the influence is even clearer, only 2 of the 24 correlation coefficients are smaller than 0.45.

These figures will probably be an important tool in investigating the relations of radiation to dynamics because they give the first time a quantitative picture of the connections".

Prof. Möller concluded with a brief review of recent attempts (by Phillips, Mintz and Hinkelmann) to incorporate radiative terms in dynamical studies.

Summaries of papers presented at subsequent sessions follow.

- Session 1: Radiation measurements during the I.G.Y.
- Session 2: Surface instrumentation.
- Session 3: Satellite and Rocket programmes.
- Session 4: Observation and computation of terrestrial radiation.
- Session 5: Transmission of solar radiation in the free air and clouds.
- Session 6: Papers on spectroscopic methods.
- Session 7: Sub-commission on Applied Solar Energy.

List of Participants

Dr. M. Alaka (WMO)
Mr. R. Anderson (Newport, USA)
Dr. A. Angstrom (Stockholm)
Prof. D. Ashbel (Jerusalem)
Dr. P. Bener (Davos)
Dr. H.J. Bolle (Mainz)
Dr. H.J. de Boer (De Bilt)
Dr. T.A. Bosua (Pretoria)
M. Perrin de Brichambaut (Paris)
Prof. F.A. Brooks (Los Angeles)
Dr. K. Bullrich (Mainz)
Prof. M.I. Budyko (Leningrad)
Dr. G. Cena (Rome)
Mr. G.J. Day (Eskdalemuir)
Dr. D. Deirmendjian (Los Angeles)
Dr. R. Dogniaux (Brussels)
Mr. A.J. Drummond (Newport, USA)
Dr. S. Fritz (Washington, D.C.)
Mr. F. Froiland (Washington, D.C.)
Dr. P.R. Gast (Cambridge, Mass.)
Dr. D.M. Gates (Boulder)
Dr. W.L. Godson (Toronto)
Dr. K. Gräfe (Hamburg)
Dr. J. Vern Hales (Salt Lake City)
Dr. H. Hinzpeter (Potsdam)
Prof. H. Hoinkes (Innsbrück)
Dr. J.T. Houghton (Oxford)
Mr. L. Jacobs (London)
Mr. WM. S. Keeler (Grenoble)
Prof. K.Y. Kondratiev (Leningrad)
Mr. G. Korb (Mainz)
Dr. S.H.H. Larsen (Tromsö)
Dr. J. Lenoble (Paris)
Dr. O. Lönnqvist (Stockholm)
Dr. R.M. Marchgraber (Cambridge)
Prof. H. Masson (Dakar)

Dr. B.W. Mc. Mullen (London)
Dr. W.E.K. Middleton (Ottawa)
Dr. W. Möller (UNESCO)
Prof. F. Möller (Mainz)
Dr. W. Mörikofer (Davos)
Prof. H.G. Müller (Munich)
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Dr. R.J. Murgatroyd (Farnborough)
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Dr. K. Ramanathan (Ahmedabad)
Dr. W.T. Roach (Farnborough)
Dr. D.Z. Robinson (London)
Dr. G.D. Robinson (London)
Prof. N. Robinson (Haifa)
Mr. F. Saiedy (London)
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Dr. H. Schieldrup-Paulsen (Bergen)
Prof. R. Schulze (Hamburg)
Dr. J. Seeley (Farnborough)
Prof. Z. Sekera (Los Angeles)
Prof. P.A. Sheppard (London)
Dr. S.D. Smith (London)
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Dr. V.J. Stakutis (Cambridge, Mass.)
Dr. K.H. Stewart (London)
Mr. J.C. Thams (Locarno)
Mr. E. Theisen (Oslo)
Mr. P. Valko (Davos)
Mr. D.O. Vickers (Nigeria)
M. Vigroux (Paris)
Prof. J. Van Mieghem (Brussels)
Dr. H. Wierzejewski (Davos)
Dr. H. Wörner (Potsdam)
Dr. G. Yamamoto (Sendai)

I. RADIATION MEASUREMENTS DURING THE I.G.Y.

M. ALAKA (W.M.O.). Material received at the World Data Centre, Geneva.

It was estimated before the event that 700 stations would be making radiation observations of some kind during the I.G.Y. Expressed as a percentage of this estimate the forms received at the W.D.C. in Geneva (July 1959) are:

Form R-0 (Station and instrument details)	41%
Form R-1 (Daily totals of radiation on a horizontal surface)	53%
Forms R-2a & R-2b (Monthly sums of hourly values of solar and sky radiation on a horizontal surface).	2.3%
Form R-3 (Daily totals of radiation balance and its components)	2.7%
Form R-4 (Monthly sums of hourly values of radiation balance and its components)	2.0%
Form R-5 (Instantaneous intensities of direct solar radiation and turbidity parameters)	9.0%

M.I. BUDYKO (Central Geophysical Observatory, Leningrad). On the Study of Geophysical Distribution of the Indices of the Radiation Regime.

Two main methods are used to study the geographical distribution of the indices of the radiation regime. The first of them is connected with the direct generalization of the data of actinometric observations. This method is comparatively seldom used to make the maps of mean values of the indices of the radiation regime, because more or less extended actinometric observations have been made at a comparatively small number of locations.

In this connexion, the other method is used more often for the compilation of maps of the indices of the radiation regime, which is based on the application of various computation methods of determining the components of the radiation balance.

This method was particularly used in some earlier studies carried out by the staff of the Main Geophysical Observatory, in which the maps of the total radiation, albedo, radiation balance of the earth's surface and of some other indices of the radiation regime have been compiled (1947-1955).

In the recent time the number of the available data of actinometric observations has been enlarged considerably due to the International Geophysical Year. This fact allows us to check the calculations made earlier and to evaluate the accuracy of the available maps of the indices of the radiation regime.

Now we have increased possibilities of applying the observational data directly to the compilation of new maps and to the development of methods of calculating the indices of the radiation regime.

In the recent studies carried out at the Main Geophysical Observatory the data of new actinometric observations have been used to perfect the methods of determining the short-wave solar radiation, long-wave effective radiation and the albedo of the earth's surface. The application of these methods has made it possible to compile more accurate maps of the radiation balance of the earth's surface.

H.C. HOINKES (Institute of Meteorology and Geophysics, University of Innsbruck)
Studies of Solar and Net-Radiation in the Antarctic (Little America V and South Pole) 1957-1958.

A. Instruments. This preliminary report deals with radiation studies, performed during the US-Antarctic Expedition 1957/58, as a part of a research programme in Glacial Meteorology, between Febr.1, 1957 and Febr.3, 1958, mainly at Little America V, 78° 11'S, 162° 10'W, elevation 44 meters above sea level.

The recording instruments used were: a) two Solarimeters Moll-Gorczynski (Kipp & Zonen, Delft), b) one Net-Radiometer Schulze (B. Lange, Berlin). Continuous records for Global Radiation and Albedo were obtained from Febr. 18, 1957 to Febr.3, 1958; for the two thermopiles and the temperature of the Net-Radiometer from March 14, 1957 to Febr.3, 1958. The non-recording instruments were a) one Actinometer Linke-Feussner (Kipp) for measuring the direct solar Radiation, also with filters OG1, RG2 and Quartz. The same Actinometer in connection with a portable mirror-galvanometer for measuring the outgoing radiation to different zenith distances. b) one Solarimeter Moll-Gorczynski (Kipp) in a Cardanic mounting for measuring the Albedo. c) two instruments especially designed for measuring the penetration of radiation into the snow cover.

B. The Intensity of Direct Solar Radiation at Little America. The Linke-Feussner Actinometer N° G 109 was calibrated in early December 1956 at Innsbruck with the bimetal Actinometer Michelson-Marten N° 346, the latter being calibrated by the Physikalisch-Meteorologisches Observatorium Davos, Switzerland. Unfortunately on December 7, 1957 after the first readings at the South Pole, the thermopile became shunted; no further observations were possible. No change of the calibration constant has to be suspected, however, between December 1956 and December 1957. 274 series of radiation measurements were obtained on 40 days at Little America V and 10 series on the 7th of December 1957 at the South Pole. Owing to the clear, dry and dustfree air the intensities of normal Indidence Radiation at 44 meters in the Antarctic are as high as in the European Alps at 3000 meters in June, being respectively for:

Solar altitude	5°	10°	15°	20°	25°	30°
Little America V	0.83	1.04	1.19	1.28	1.35	1.41
European Alps, 3000 m, June	0.84	1.04	1.18	1.28	1.36	1.41

The above values are expressed in cal/cm^2/min.

The intensity measured at the South Pole, viz. 1.50 cal/cm^2/min for 22.5 degrees sun's elevation at 2800 meters above sea level fits well with the intensities for Little America are given according to IPS 1956 for actual solar distance.

C. The Albedo of the High Interior of the Antarctic Continent. 100 series of Albedo were measured between December 5, 1957 and January 4, 1958 within one kilometer of the Amundsen - Scott IGY South - Pole Station and 15 series of Albedo at Byrd Station (80°S, 120°W, 1515m above sea level) on January 20 and 21, 1958. The measuring sites were chosen in a way to cover all types of snow surfaces without preferring one single type. 25 percent of the 115 series gave albedo values over 0.90 (max. 0.934); being typical of extremely fine grained closely packed snow, without any sign of wind erosion. 22 percent of the values lay below 0.87 (min. 0.843), being typical of wind-exposed older surfaces with coarse grain and strong wind carving. 53% were found between 0.87 and 0.90, representing the fresh, fine grained snow, showing signs of slight to moderate wind action. The average albedo for the inland ice, measured during December and January, was 0.886. Since the values for midsummer should be the lowest throughout the year, the average albedo for the whole light-season on the high inland ice will be close to 0.90. The lowest albedo measured at Little America was 0.75, but even in midsummer the albedo of freshly fallen snow reaches values up to 0.90. A detailed analysis of Global Radiation and Albedo at Little America will be given, after the evaluation of the records has been finished.

D. The Calibration of the Schulze Net-Radiometer. The Schulze Net-Radiometer remained outdoors from March 14, 1957 to Febr. 3, 1958, thus withstanding the severe climatic conditions of the Antarctic winter night, i.e. temperatures down to -52°C and winds up to 128 km/h, without ever giving serious trouble.

Between July 3 and November 9, 1957, 25 calibrations for both thermopiles of the net-radiometer were performed at temperatures ranging from -7.5 to -48°C, using a black body filled with an ice water-mixture. The calibration constant for long-wave radiation turned out to be a function of the temperature of the instrument, the constants being respectively in cal/cm²/min per scalepart for 5mV-range:

$K_{lu} = 0.0047\ (1 + 0.0034T_i)$ for the upfacing thermopile
$K_{ld} = 0.0075\ (1 + 0.0022T_i)$ for the downfacing thermopile.

Until Nov. 25, 1957, 55 calibrations for short-wave radiation were performed, using the Linke-Feussner Actinometer, between 4.85 and 31.6 degrees of solar altitude and -41 to -8°C. A constant value was not reached for solar altitudes less than 15°. Using the the 29 calibrations made at solar heights over 13.5°, the dependence of the EMF on temperature was checked for temperature ranging from - 8 to -35°C, the result being the the same as for long-wave radiation. The calibration constant for short-wave radiation in cal/cm²/min per scalepart for 5mV-range being:

$K_{su} = 0.0059\ (1 + 0.0034T_i)$ for the upfacing thermopile
$K_{sd} = 0.0094\ (1 + 0.0022T_i)$ for the downfacing thermopile.

The difference between the calibration constants for long- and short-wave radiation for the same thermopile, i.e. about 20 percent, seems surprisingly large and not easy to explain. Since the thermopiles are more sensitive for long-wave radiation, two possibilities exist: firstly the thermopiles being more black for long-wave radiation and secondly the polyethylene bulbs being more transparent in the infra-red than in the visible part of the spectrum. A discussion of this problem seems highly desirable, and if by other experiences a difference of the same order of magnitude is confirmed, an instruction should be issued for evaluating the records for periods with short- and long-wave radiation at the same time.

E. The Net-Radiation During the Winter Night (April to August 1957). The frequency distribution for 3672 hourly mean values of Net-Radiation from April 1 to August 31 shows a broad maximum between Zero and -0.03 cal/cm²/min, the mean being -0.012 cal/cm²/min. 904 hours or 25 percent of the winter had incoming net-radiation, the mean for 830 hours with a low overcast being + 0.0035 cal/cm²/min. The average for 285 hours with heavy blowingsnow, - 0.0018 cal/cm²/min, shows an energy loss to be typical of non-inversion conditions, even with the air densely filled with drifting snow particles. The average net-radiation for 929 hourly intervals with cloudless skies amounts to - 0.0264 cal/cm²/min, the values decreasing with decreasing temperature, as found by other authors. The relation as shown by group-means is the following:

Temperature (°C)	-15.3	-19.2	-26.0	-32.4	-43.1	-47.9
Net-Radiation (cal/cm²/min)	-.049	-.040	-.040	-.029	-.024	-.023

Although the height and temperature of the inversion controls the net-radiation largely, there remains still a non-linear relation between net-radiation and cloudiness. Calculated for daily totals the group means are as follows:

Cloudiness	0.4	1.5	2.5	3.6	4.6	5.5	6.6	7.6	8.6	9.7
Net-Radiation (cal/cm² day)	-35.2	-34.4	-29.4	-28.7	-25.5	-17.1	-10.9	-11.2	-13.0	+0.6

The monthly totals of net-radiation (cal/cm²) are:

	April	May	June	July	August
Total net-radiation	-435	-660	-478	-546	-526
Mean cloudiness (1/10)	5.8	5.0	7.0	5.3	6.6
Mean temperature (°C)	-33.2	-30.9	-24.1	-35.4	-34.4

Between June and August 1957 on 11 days 125 series of measurements of the outgoing radiation to different zenith distances were performed with the Actinometer Linke-Feussner. If the value read, the instrument being pointed towards the zenith, was set equal to 100 percent, the values to zenith distances in steps of 10 degrees were respectively (mean for 125 series):

Zenith distance	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°
Outgoing radiation (%)	100	99.1	97.7	85.2	90.9	85.0	76.3	64.9	46.9	23.0

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H. WIERZEJEWSKI (Davos Observatory). Evaluation of the Different Components of the Radiation Balance at Various Altitudes.

During the Geophysical Year records of the short-wave and long-wave radiation fluxes were taken in Switzerland at four stations, at Basle, 317 m a.s.l., Locarno, 379 m, Davos-Platz, 1590 m, and Davos-Weissfluhjoch, 2670 m. The radiation receivers were thermopiles with glass hemispheres for short-wave fluxes and with "Lupolen" (polyethylene) hemispheres for the sum of short- and long-wave fluxes; the recording instrument was a Speedomax recording polentiometer.

The daily variation of the different components of radiation balance for clear and for overcast days is demonstrated by diagrams for the two high-altitude stations Davos-Platz and Davos-Weissfluhjoch, at 4, 5 km distance from each other but with a difference of altitude of 1080 m. The characteristic differences in the daily variation for the two stations and two weather situations are briefly discussed. Of particular interest is the high intensity of the reflected short-wave radiation, caused by the high albedo of the snow cover in the mountains during half the year. On the other hand, the important part of the long-wave fluxes in the daily sums of the radiation balance is confirmed.

Finally, the single steps of calculation which are necessary for the evaluation of the hourly mean values of the single components of the radiation balance are discussed. In contrast to the easy determination of the short-wave components the evaluation of the long-wave components requires a considerable effort of calculation. It is therefore not astonishing that hourly values of the long-wave components have so far hardly been published by any station - a sign of the importance of automatic computation and integration of the components.

S. FRITZ and T.H. MACDONALD (U.S. Weather Bureau Washington, D.C.). Some Normal-Incidence Solar Radiation Observations During the I.G.Y.

During the International Geophysical Year many new solar radiation observations were taken at many places. In particular, new stations were installed in Antarctica and one was installed at the Mauna Loa Observatory in Hawaii. Some of the normal-incidence solar radiation data which have so far been evaluated are presented in this paper. In taking normal-incidence observations, the observers are instructed to point the instrument to the sun only in those cases when no clouds appear in front of the sun. If we now intercompare the mean value of radiation at one station with that at another for the same optical air mass then a certain subjectivity is introduced into the results, because many times the sky is covered with a very thin milky veil. Some observers consider that the sky is then covered by a thin cirrus cloud and they do not take normal-incidence observations under those conditions.

We may attempt to get around this uncertainty taking the very clearest days as an example of what the clear day transmission really was. However, some subjectivity arises in this case too; a single extreme value is often incorrect because of slight errors of recorder settings or for other reasons.

In spite of these difficulties, the major differences between stations still appear. For example, stations at high elevations invariably have higher transmissions than those at much lower elevations and stations in polar regions have higher transmissions than those in middle or tropical latitudes. These results are indicated in Tables 1 and 2. In Table 1, typical normal-incidence solar radiation values, on the International Pyrheliometric Scale, are shown for the spring months. The data have been reduced to sea-level pressure. Both the mean values of radiation and the maximum values computed as indicated above are shown in the table. We see immediately that the radiation values for Little America and for Mauna Loa are both definitely higher than the values for Blue Hill and for Tucson. Mauna Loa has an elevation of about 11,000 feet, while the other stations are nearer sea level. Little America is at a much higher latitude.

higher latitude than any of the other stations and presumably has a less polluted atmosphere with smaller amounts of water vapor. The values at Mauna Loa seem to be slightly higher than those at Little America. And this is true for both the mean and the maximum values. However, the values are close enough together so that the reality of the difference is in doubt. The same thing may be said for Blue Hill and Tucson. Their values are in general, so close together that the difference may not be real.

In Table 2, similar data are presented for the summer period. Data for the South Pole are available while those for Little America are not yet evaluated.

The values shown in Table 1 and 2 have been adjusted for the mean distance of the sun from the earth. There is considerable interest, for practical application, in the actual values as received at the earth's surface. Such values have also been computed and are given in graphs not reproduced in this summary. The variations of the actual climatological data from the values shown in Tables 1 and 2 occur because the sun is nearer to the earth in the southern hemisphere summer. As a consequence the values at the South Pole for the summer are appreciably higher than those at Mauna Loa in summer. In the Spring the differences are not so great, but there still is a small increase at Little America relative to the stations in the north. Thus, for the mean value of radiation the values at Little America actually become somewhat higher than those at Mauna Loa, although the difference is very small and may not be real. For the maximum values of radiation, that is on the clearest days, Mauna Loa apparently has higher values of radiation than Little America even in the climatological values which are not much changed from those in Table 1.

Typical Normal-Incidence Solar Radiation Values I (ly/min)
(Reduced to mean distance from sun)
Air-Mass (Reduced to sea-level pressure)

Table 1. Spring (March 21 - June 21, 1958 - Sept. 23 - Dec. 22, 1957).

Station	Pressure (mb)	2		3		4	
		I (mean)	I (max)	I (mean)	I (max)	I (mean)	I (max)
Little America, Antarctica	987	1.35	1.38	1.22	1.26	1.13	1.18
Mauna Loa, Hawaii	680	1.39	1.46	1.24	1.32	-	-
Blue Hill, Massachusetts	980	1.18	1.29	0.99	1.12	0.85	0.99
Tucson, Arizona	925	1.20	1.30	1.04	1.16	0.90	1.04
South Pole, Antarctica	725	-	-	-	-	-	-

Table 2. Summer (June 21 - Sept.23, 1958 - Dec. 22, 1957 - March 21, 1958)

Station	2		3		4	
	I (mean)	I (max)	I (mean)	I (max)	I (mean)	I (max)
South Pole, Antarctica	1.46	1.48	1.34	1.35	1.22	-
Mauna Loa, Hawaii	1.41	1.46	1.26	1.32	-	-
Blue Hill, Massachusetts	1.17	1.28	0.99	1.16	0.87	1.04
Tucson, Arizona	1.13	1.25	0.96	1.12	0.84	1.00

G.S. DAY (Eskdalemuir Observatory, Dumfries, Scotland). Solar Radiation Measurements from British Ocean Weather Ships.

Recommendation 21 of the I.G.Y. Meteorological Programme stresses the importance of radiation observations at a sufficiently dense network of stations in order that the atmospheric circulation problem may be the more effectively examined.

With the object of closing the large gap in the network of stations represented by the oceans, the U.K. Meteorological Office investigated, late in 1955, the possibility of mounting Total Hemispherical Radiation Solarimeters and Ventilated Net Flux Radiometers on Ocean Weather Ships.

After initial trials it was found possible to mount solarimeters in an oil damped gimballed ring mounting in such a manner that the ship's motion had no effect. Recording was by standard potentiometric recorder and operation has proved quite trouble free, nearly a complete year of record having been obtained during the I.G.Y. on one station continuously occupied by U.K. ships.

Stabilisation of ventilated net flux radiometers in roll by a simple pendulum system proved effective and a system was devised in which two stabilised radiometers were mounted on booms projecting from each side of the ship and they were shielded so that each only saw the upper and lower half hemispheres away from the ship. In this way, by recording the output of two instruments, matched in sensitivity, in series on a potentiometric recorder, one effectively had an instrument seeing a complete hemisphere but not the supporting vessel.

The net flux radiometers have not proved entirely successful, largely due to bad engineering of the trunking conveying ventilating air to the radiometers. However, some useful record has been obtained and modified mountings which show considerable promise are now under test.

Calibration of instruments is straighforward in principle and merely involves comparison with a standardised instrument of similar type. In the case of solarimeters this is a simple process. In the case of radiometers the standardised instrument must be of the unscreened type and the shipboard radiometers must therefore be removed from the ship, together with ancillary equipment, and the comparison carried out over some convenient uniform, unobstructed land surface.

The radiometers used develop asymmetry in use and symmetry of response should be checked regularly. This is virtually impossible with the form of mounting originally used, a new version now under test permits very easy checking, even at sea.

P. WALKO (Davos Observatory). The Actinometric Determination of Turbidity Parameters and of Precipitable Water at Various Altitudes.

The Swiss IGY network of accurate thermoelectric actinometers equipped with Schott glass filters OG 1, RG 2 and RG 8 offers very suitable material for a detailed investigation on turbidity conditions in their dependence on altitude a.s.l. The turbidity coefficient B, the wavelength-exponent α and the quantity of precipitable water W were determined by Schüepp's (1, 2) method at five stations at various altitudes in the Alps.

The characteristic differences of turbidity at various altitudes were examined by frequency distributions of B for one winter and one summer month, furthermore mean values of α were calculated for the same periods. The mean features and - for the purpose of comparison - the corresponding characteristics of measurements at Stanleyville (3) (Belgian Congo) are combined in Table 1.

Table 1. Actinometric turbidity parameters from Swiss IGY Stations and Stanleyville

Station	Position			Mode of B		Mean value of α	
	Latitude	Longitude	Altitude m	Winter	Summer	Winter	Summer
Locarno-Monti	46°10'N	8°47' E	380	36	80	1,90	1,75
Mte Brè	46°11'	8°48'	1030	-	-	-	-
Cimetta	46°11'	8°48'	1640	-	-	-	-
Davos	46°48'	9°49'	1590	25	55	1,75	2,00
Weissfluhjoch	46°49'	9°50'	2670	15	35	1,80	2,05
Stanleyville	0°31'N	25°11' E	415	70	320	1,30	1,60

The reliability of actinometric determinations of precipitable water by means of the red filter RG 2 were checked with simultaneous values of W obtained from direct humidity soundings. The result of such a comparison led for Davos to the relationship

$$W_{actin.} = 1,05\ W_{direct} - 0,07$$

with a correlation coefficient of 0,90.

Turbidity-altitude profiles of the daily mean of B and W, deduced from simultaneous measurements, show a characteristic exponential diminution; on the other hand, no regular variation in α could be found. The altitude distributions of B and W show a very good distinction for the different synoptic air masses. Hourly data of a selected day with strong changes of turbidity in the lowest layer during the day indicate a distinct haze transport to higher levels. The vertical mixing was greatest in the early afternoon and had a rapid decrease with altitude.

Finally it can be demonstrated that α values of higher accuracy can be obtained by using the filter RG 8 instead of RG 2, especially at stations at higher levels.

This short report can give only some examples. A thorough study based on the whole material of Swiss IGY actinometric measurements is under preparation.

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Minor contributions to this session were made by Mr. J. MacDowall, Royal Society Antarctic Expedition (paper read by G.D. Robinson) on the annual changes in the radiation balance at Halley Bay (75°31'S. 26°36'W.) during the I.G.Y. and by H. Hinzpeter (Potsdam) on some radiation measurements at sea from the U.S.S.R. research ship "Lomonossov", using a Schulze type meter.

DISCUSSION

Discussion mainly centred on the difficulty, disclosed in the papers of Hoinkes and Wierzejewski of allowing for the different sensitivity of the Schulze-type balance meter in the visible and infra-red regions. H. Hinzpeter and W. Schüepp (Meteorological Service, Belgian Congo) reported similar difficulties due to absorption in the polyethylene shield. Schüepp claimed to have reduced the effect by allowing small ventilation of the inside of the polyethylene to reduce its temperature excess. There was no general agreement on the precise cause of the difficulty, nor on a cure. Ventilated radiation balance meters were not discussed in detail, but it was stated that Antarctic experience with them showed the need for substantial temperature and other corrections.

2. SURFACE INSTRUMENTATION

A. ANGSTRÖM and A.J. DRUMMOND (The Eppley Laboratory, Inc., Newport, Rhode Island). On the Influence of Thickness and Temperature on the "Cut-Off" Characteristics of Glass-Filters.

Schott glass filters OG1, RG2 and RG8 have been investigated with respect to the dependence of the lower sharp wavelength cut-off on filter thickness and temperature. Typical values of the main cut-off characteristics are presented. Details of instrumentation and technique are in course of publication in the Journal of the Optical Society of America and of results for typical filters in the Quarterly Journal of the Royal Meteorological Society.

J.C. THAMS (Osservatorio Ticinese, Locarno, Switzerland). Calibration of Radiation Instruments under Different Conditions of Turbidity.

a) A comparison of Linke-Feussner actinometer and Angstrom pyrheliometer observations is discussed. Standard deviation of the ratio is 0.7 per cent. No influence of turbidity is observed. Wind is found to have a considerable influence on both instruments - the mean value of the ratio does not change in windy conditions, but the dispersion increases. It is also necessary for the instruments to be in good thermal equilibrium with their surroundings. The value of thermoelectric actinometers in pyrheliometry is emphasised.

b) Calibration of the Moll-Gorczynski pyranometer by shading is discussed. No notable effect of turbidity is found, but there is a tendency for smaller dispersion on hazy days (attributed to the greater influence of wind on clear days). The temperature coefficient of the instrument as a whole is found to be 0.2 to 0.4 per cent per degree C that of the thermopile alone to be about 0.1 per cent per degree C.

c) Calibration of bimetallic (Robitzsch) pyranographs. Day to day comparison against a thermoelectric pyranograph is greatly superior to shading methods. No dependence of the mean factor on cloudiness is found, but dispersion of calibration on clear days is lower. The standard deviation of the ratio of daily totals obtained by bimetallic and thermoelectric pyranographs is 6 per cent.

R.M. MARCHGRABER (U.S. Army Signal Research and Development Laboratory) and A.J. DRUMMOND (The Eppley Laboratory, Inc., Newport, Long Island). A Precise Radiometer for the Measurement of Total Radiation in Selected Spectral Bands.

An improved model of the pyranometer type of radiometer is described. The principal features of the design are (a) a new thermopile detector with a receiving surface which is non-selective with regard to the wavelength of the incident energy, (b) optical compensation for reflection losses in the detector system, (c) thermistor circuitry compensation for variation of thermopile sensitivity with ambient temperature, and (d) facility of exposure of the receiving surface in planes other than the horizontal. The employment of interchangeable hemispherical envelopes of clear and filter glass enables the separation to be made of solar radiation into well-defined wavelength intervals.

The principal physical characteristics of a radiometer of the type discussed are (a) temperature dependence of sensitivity, (b) incident energy-radiometer emf relationship, (c) selectivity of the receiver with respect to wavelength, (d) cosine error, (e) stability of performance, (f) sensitivity and (g) response time. A test program was established to investigate these characteristics under controlled laboratory conditions. The results of the tests conducted are presented in tabular form.

(a) Temperature dependence

% Deviation of radiometer sensitivity from 0°C value

Temperature	-40°C	-30°C	-20°C	-10°C	0°C	+10° C	+20° C	+30°C	+40°C	+50°C
Thermopile only	+11.4	+8.5	+5.7	+2.9	0	-2.9	-5.7	-8.5	-11.3	-14.0
Thermopile compensated	+1.3	+0.8	+0.4	+0.1	0	-0.1	0	+0.2	+ 0.6	+ 1.1

(b) Energy-output relationship (linearity of response)

I - Distance from source in cm III - Radiometer (millivolts)
II - Thermopile 2427 (millivolts) IV - Thermopile/Radiometer

I	II	III	IV
246.8	0.80	0.72	1.11
200.8	1.15	1.04	1.11
167.8	1.66	1.50	1.11
123.3	3.11	2.83	1.10
90.0	5.60	5.15	1.10
79.0	7.18	6.55	1.10
66.2	10.63	9.62	1.10_5

Thermopile 2427 is an Eppley Laboratory sub-standard thermopile with a linear response characteristic over a wide range of radiation intensity. Source maintained constant throughout.

(c) Selectivity of receiver

Temperature °C	?	2800	1700	1000	800	500	100	50
Max. radiation μ	0.35	0.95	1.5	2.3	2.7	3.7	7.7	9.0
Thermopile: Parsons' black/ Thermopile: gold black	0.93	0.91	0.91	0.90_5	0.91	0.91	0.92	0.91_5

The data in this table represent a comparison made of the response of two different thermopiles, one with a receiver coating of Parsons' black and the other with gold black (generally accepted to be a non-selective absorber from the ultra-violet out to wavelengths of at least 40μ in the infra-red region. The energy source in the first column was a mercury arc lamp with filter restricting the output to the 270-380 mμ band; that in the second, a tungsten-filament lamp; that in the third, a carbon-filament lamp; that in the fourth - sixth, a high-temperature blackbody; and that in the seventh and eighth, a low-temperature blackbody.

(d) Cosine error

Newport	L.A.T.	Solar elevation	Radiometer constant (1)
19 August 1958	11.10	60°	7.20
	12.59	59	7.17
	14.34	46	7.27
	15.50	33	7.40
	16.58	20	7.34
	17.50	10	7.22
(1) mv per cal cm^{-2} min^{-1}			Mean 7.27

This test was carried out in the customary manner with the aid of a normal incidence pyrheliometer, the radiometer being screened from the sun by means of a small masking disc simultaneously with the standardizing measurements of direct solar radiation. Laboratory based support for these figures was also obtained. Before attempting such tests, it was verified that there was no azimuth influence (i.e. the receiver was truly flat and properly levelled).

(e) Stability of performance

This was assessed, in the laboratory, in two ways, viz. (1) by repeating the measurement of radiometer output, when exposed with receiver horizontal to a tungsten lamp over periods of 2-3 hours at a time, and (2) by tilting the radiometer from the horizontal receiver position through 90 degrees. Both types of test were made with radiation intensity maintained constant throughout each series.

(1)

28 June 1958 0.942 +41°C		30 June 1958 0.964 -40°C		3 July 1958 1.170 + 3°C	
Time(h)	mv.	Time(h)	mv.	Time(h)	mv.
0.	6.89	0	7.10	0	8.52
0.5	6.90	0.5	7.10	0.5	8.50
1.0	6.89	1.0	7.10	0.75	8.50
1.5	6.90	1.5	7.09	1.0	8.50
1.75	6.89	2.0	7.10	1.25	8.49
2.0	6.89	2.5	7.09	1.3	8.51
Unit of measure = cal cm^{-2} min^{-1}					

cal.cm $^{-2}$min $^{-1}$		0.190	1.149
Temperature 25°C		Radiometer output in mv. (mean values over a 2-hour observational period).	
Radiometer surface	horizontal 45° vertical	1.375 1.380 1.380	8.34 8.35 8.37

(2)

(f) Sensitivity. This was established to be generally 7 - 7.5 mv. per cal.cm^{-2}min^{-1} (with the thermistor circuitry in position).

(g) Response time. This was established to be almost exactly 30 seconds for 98 per cent response (with the thermitor circuit in position).

The dependence on atmospheric pressure of the sensitivity of this radiometer, with the whole system open to the ambient air, was also investigated. It was found that the sensitivity variation over a pressure range of 760-100 mm (i.e. corresponding to a range of altitude of 50,000 ft.) did not exceed 2 per cent.

In the investigations discussed in this section of the paper, the radiative intensity varied between 0.1 and 1.5 cal. cm^{-2}min^{-1} according to the type of test and the nature of the energy source employed.

A.R. KAROLI (The Eppley Foundation for Research) and A.J. DRUMMOND (The Eppley Laboratory, Inc., Newport, Long Island). The Dependence on Atmospheric Pressure of the Response Characteristics of Thermopile Radiant Energy Detectors.

An account is given of an investigation into the pressure dependence on the sensitivity of eight different types of thermopile detector over the pressure range 760 - 10^{-5} mm. The change in the response time constant is also discussed. Results are presented in Tables I and II.

Table I. Increase in sensitivity of standard-type thermopiles with decrease in atmospheric pressure (in per cent deviation from sea-level value)

Thermopile	500 3.5	100 15	10 30	1 45	10^{-1} 65	10^{-2} 80	10^{-3} 95	10^{-4} 110	10^{-5} 130	mm km
A*	1	2	3	13	18	22	24	30	35	
B	0	0	1	7	37	74	82	82	83	
C	0	-2	0	10	49	90	100	103	104	
D	1	2	6	16	64	104	121	125	126	
E	1	2	2	9	41	114	143	145	146	
F	-1	-4	3	20	85	126	147	152	154	
G	1	1	1	8	52	124	156	161	163	
H	0	0	0	-10	-55	-79	-83	-84	-85	

Explanation

A Kipp (Moll) 14-junction manganin-constantan, rectangular, heat-sink type
B Eppley 12-junction Bi-Ag, spectrum, compensated type
C Eppley 10-junction PtRh-AuPd, pyrheliometer type
D Eppley 15-junction Bi-Ag, new development, circular, heat-sink type
E Eppley 4-junction Cu-constantan, circular, compensated type
F Eppley 50-junction PtRh-AuPd, pyrheliometer type
G Eppley 8-junction Bi-Ag, circular, compensated type
H Volochine 24-junction manganin-constantan, circular, absolute type.

Table 2. Thermopile time constants (seconds)

Thermopile	760	10^{-2}	10^{-3}	10^{-5}mm	Thermopile	760	10^{-2} mm
A	14			26	E	4	6
B	2	5			F	30	
C	20				G	5	12
D	29		70		H	7	25

A.J. DRUMMOND (The Eppley Laboratory, Inc., Newport. Long Island) and R.M. MARCHGRABER (U.S. Army Signal Research and Development Laboratory).

New Instrumentation for the Automatic Recording of Solar and Sky Ultra-Violet Radiation.

A new approach to the detection of total sun and sky ultra-violet radiation is outlined. An account is given of the techniques adopted for amplification of the signal and of its matching to a recording potentiometer scaled directly in energy units. The method developed to standardize the records is discussed.

Essentially, the separation of the ultra-violet constituent is achieved through the employment of Schott UG11 filter glass which has the following approximate spectral transmission characteristics for a 4.0 mm thickness:

λ	T	λ	T	λ	T
250 mμ	.00	300 mμ	.60	350 mμ	.63
260	.01	310	.66	360	.53
270	.07	320	.69	370	.32
280	.25	330	.70	380	.07
290	.47	340	.67	390	.00

There is a secondary transmission band (in common with practically all broad-band type UV filters) centered at 720 mμ but, here, the transmittance, in the two glass melts examined so far, nowhere exceeded .01.

However, because of the great intensity of solar radiation around 700 mμ, as compared with that of wavelength shorter than 390 mμ, it was considered desirable to attempt to eliminate red or near infra-red transmission from the measurements. This was accomplished by the use of two radiometers (pyranometers) so connected that the thermopile outputs are in opposition. Each radiometer incorporates an innermost, precision ground, 50 mm diameter (partial, 20 mm height) hemisphere of fused quartz of such optical quality that the transmittance over the wavelength interval 260-380 mμ is uniform at .92. The "ultra-violet sensing radiometer" has a second concentric hemisphere of UG11 glass (64 mm base diameter) and the "compensating radiometer", two concentric hemispheres additional to the quartz one, viz. UG11 of 80 mm diameter and OG1 of 64 mm diameter. This arrangement, in operation, appeared to be an improvement over one where both UG11 hemispheres were chosen to be 80 mm in base diameter. The Schott OG1 glass, although opaque to the main transmission band of the UG11 filter is, of course, highly transparent (T = .90) to its secondary band.

The pair of radiometers is selected so that the sensitivity (through the quartz envelope only) of each is practically the same, the one of higher sensitivity being reserved for the compensating unit. But this is not of major importance since it was found that the radiation transmitted by the UG11 filter, in its secondary band, rarely exceeds, in intensity, 10 per cent of that of the pure ultra-violet transmission. Hence, systematic inequality of 10 per cent (i.e. through thermoelectric and optical differences) in the two systems, with the differential method adopted ought not to introduce errors in excess of about one per cent, generally, into the record of ultra-violet radiation.

Provision is made for compensation, for the effects of thermal inequilibrium between the two radiometers (mainly a function of infra-red radiative exchange within the systems and influenced by convective heat transfer, externally, by wind and precipitation) by a variable microvolt source.

T.A. BOSUA (Weather Bureau, Union of South Africa). The Integration of Semi-Continuous Radiation Records by Means of a Simple Analogue Computer.

An integrator capable of reducing observations of solar and terrestrial radiation recorded semi-continuously by means of Hartman and Braun two-channel dotted line recorders (coupled to the various radiometers) directly to radiation energy units, is described. The accuracy obtained with the instrument was found to be as good or better than that of manual methods, (errors smaller than 1%), while occasional large errors (as found with manual methods) are practically eliminated. Furthermore the time taken to reduce the records is diminished to less than one fifth of the time necessary when the records are processed manually. The same principle (ball and disc integrator) can be utilized to evaluate practically any continuous (and many semi-continuous) records.

W. SCHUEPP (Meteorological Service, Belgian Congo). Conversion of Spherical Radiation Data toTotal Radiation.

Data on total radiation may not be collected from a dense network of stations because instruments of the thermoelectric type need special care, are rather expensive and the computing of data takes much time. Five years experience with a network of stations equipped with the metallized spherical Bellani-type pyranometer in the Belgian Congo suggests that this instrument may fill this gap at least in low latitudes.

At Stanleyville, just on the equator, a simple regression-line allows an estimation of daily total radiation with a mean error of $\pm$ 10% for daily sums and $\pm$ 5% for 10-day or monthly values. A second order curve through the origin fits the data much better. At Léopoldville (4° Southern latitude) the scatter of the data is greater, suggesting the use of seasonal conversion tables (especially for the dry winter season). At Elisabeth-ville (11° Southern latitude) the seasonal variation is more striking.

To solve the problem of conversion from daily sums of spherical radiation to daily total radiation a theoretical approach is made, introducing successively the astronomical, atmospherical and meteorological factors influencing the measurements. It is shown to be easier to study the ratio between these radiation data than the absolute values of either set.

A sufficient approximation is reached when considering only the difference between latitude and declination, the albedo of the ground and the observed values G_s of spherical radiation. Taking into account atmospheric extinction, the ratio between both kinds of measurements does not change very much in spite of a rather strong reduction of the absolute values. The same is true when extinction by aerosol (haze) is included. The stronger the extinction, the smaller is the influence of latitude. Diffuse radiation coming from a cloudless sky does not depend at all on latitude, but the much higher intensities of sky-light near the horizon affects the spherical more than the horizontal receiver. The opposite is observed with a completely covered sky, the zenith is then brighter than the horizon. For intermediate cases of cloudiness between the extreme cases of 0 and 1 it is necessary to consider the following three components of radiation:

1°) direct solar radiation
2°) diffuse radiation from the blue sky
3°) diffuse radiation of the clouds

For each component statistical relations as a function of cloudiness are established and the final value of the ratio between daily radiation is derived from the sum of these three components. Finally the reflection of radiation by the ground (albedo) α which affects the spherical receiver only, is introduced. The final relation is an equation of the second or third degree having the form:

$$G_h = a.G_s + b.G_s^2 + c.G_s^3$$

where G_s is the daily radiation on a sphere, and G_h the daily total radiation

The doefficients a, b and c may be expressed by a formula valid for values of (latitude(declination) up to 45°. For higher values (latitude-declination, a, b and c may easily be interpolated from a table.

$$a = 2.25 / (1 + 1.05\alpha) + 0.0001 (\varphi - \delta)^2 / (1 + 10\alpha)$$
$$b = 0.00125 \left[1 - 0.001 (\varphi - \delta)^2\right] / (1 + 8\alpha)$$
$$c = 0$$

The accuracy of Bellani measurements will be treated in detail in a later work; the three tests in Belgian Congo show already that there is no systematic difference between theory and observation greater than 5% when comparing the new Kipp-solarimeters with the Davos-Bellani-type instruments.

DISCUSSION

In this session the most lively discussion arose on the paper by Thams. Schuepp reported, in support of Thams' results, that at Leopoldville the effect of haze on the calibration of pyrheliometers was found to be very small. On the other hand Hinzpeter, at Potsdam had found a great dependence on turbidity in the ratio between readings of a Linke-Feussner actinometer and an Angstrom pyrheliometer with long tube.

In reply to questions Marchgraber stated that the thermistors used in the temperature compensating circuit of the instrument described by Marchgraber and Drummond had a high degree of stability over several years if kept in darkness.

III. SATELLITES AND ROCKETS PROGRAMMES

S. FRITZ (U.S. Weather Bureau). The Meteorological Satellite Program in United States. (This paper was written with the support of the National Aeronautics and Space Administration).

Meteorology deals with world-wide phenomena and for the first time the artificial satellite will make it possible to obtain observations from all over the world. In addition to improved geographic coverage, satellite observations will provide types of measurements which have only been rarely made.

Cloud Observations

Photocells - Vanguard II. An experiment to determine cloud cover, designed by the U.S. Army Signal Research and Development Laboratory, was launched in the Vanguard II satellite on February 17, 1959. This spinning satellite was a sphere limited in size to 20 inches in diameter and in weight to 21 1/2 pounds (1,2). It contained two photo cells sensitive in the region 0.6 to 0.8 microns which were mounted at 45° to the spin-axis. The photocells had a 1° angular opening and were supposed to sweep out adjacent areas on the earth's surface in successive sweeps as the satellite moved forward in its orbit. The clouded areas, being brighter than the cloudless ones, generated a variable signal which was stored on magnetic tape. This tape was played back when the satellite passed over a ground readout station.

It was found that the signals in each sweep indicated that the photocells and the magnetic tape were working well. In order to display cloud cover over a large region it was intended to feed the individual sweeps into an oscilloscope to generate a television-like picture. But, unfortunately in the case of Vanguard II the motions and the orbital elements of the satellite were not precise enough to permit this. The most damaging effect was caused by the precession of the spin-axis itself which did not stay fixed in space. As a consequence no results have yet been obtained from the satellite although work is still continuing.

Television Cameras - Project TIROS. With greater weight capability than 21 pounds, television cameras can be used or else satellite motions might be controlled to permit scanning by photocells. Television cameras will be used on the so called Project TIROS satellite (3) which will be launched possibly within the next year, under the management of the National Aeronautics and Space Administration, (NASA). The satellite will include one or more television cameras: according to latest plan there will be two cameras each pointing along the spin-axis. One camera will have a field of view of about 700 miles on a side with a resolution of approximately 1.5 miles at the sub-satellite point. The other camera will have a smaller field of view with a higher resolution. The television camera takes an instantaneous snapshot of the field of view and can therefore give cloud detail, including cloud amount, cloud type and cloud patterns over a relatively wide range of satellite motions.

Future Plans. Location and interpretation of the cloud pictures will be simpler on an attitude stabilized satellite; that is, a satellite on which the cameras can point continuously down towards the earth. Future generations of satellites will include such television cameras. Moreover, the orbit in future generations of satellites will be a quasi-polar orbit. The orbits of Vanguard II and of the Project TIROS are not polar orbits reaching in the latter case perhaps up to about 50° north and south latitude, and in the case of Vanguard II to 33° north and south. Still further in the future a stationary satellite, at an elevation of 22,000 miles, may become a reality; that is, one which stays continuously over approximately the same point on the earth. It will then be possible to "look" continuously at selected areas on the earth to notice important events such as storm development and measurement; it will also be possible to scan large sections of the earth quickly from a single satellite.

Quantitative Radiation Measurements. Plans are also being formulated for making measurements of the radiative heat budget of the planet and of the atmosphere, and to make measurements in broad spectral regions of the emission from the earth and from the atmosphere. Three experiments are now well along in the planning stage. The first two involve measurement of the heat budget of the atmosphere and of its variations in time and space with an experiment devised by Professor V.E. Suomi of the University of Wisconsin (2); one of these will be included in the Vanguard series. This involves the measurement of the temperature of four spheres placed on the antenna of the satellite. One sphere is painted black, one sphere is painted white and the two other spheres are coated with a Tabor surface; at least one of the Tabor spheres is shielded from the sun. The temperatures of each of the spheres will be recorded on a magnetic tape and played back to a receiver on the ground on command in the case of the Vanguard series. From these temperatures it will be possible to compute the direct solar radiation, the solar radiation reflected from the earth and atmosphere, and the long wave radiation emitted from the Planet as each one impinges on the satellite. These omni-directional sensors introduce some difficulty in attempting to get geographic distributions because a satellite "sees" such a large area on the Earth.

To overcome this problem of the very large areas seen by the satellite, later satellites will have radiation sensors with small angular openings and for several wave length intervals. The present planning for an early satellite suggests that these spectral intervals will be designed to measure:

(1) Total reflected solar radiation.
(2) Total emitted infra-red radiation.
(3) Emission in the water vapor "window".
(4) Emission in the 6 micron water vapor band.
(5) Cloud reflection.

Directional sensors, however, also introduce complications because in many cases the quantity desired is the flux passing through a horizontal surface and this must be inferred from the measurements taken at one perticular direction. Corrections based on theory and empiricism will enter into this problem. For the more distant future consideration will be given to the possibility of measuring the composition and temperature of the atmosphere and of the temperature of the earth's surface and of cloud tops. The distribution of clouds without regard to their temperature, both day and night, will be obtained by measurements with the television cameras during daytime, and at night with some of the filters already mentioned above, although the spatial resolution will probably be very poor for the first nightime cloud measurements. If the temperature and composition of the atmosphere can be measured by infra-red emission, it will apparently be necessary to mount spectrographs on the satellite to measure the emission from the atmosphere in narrow wave length bands at selected places in the spectrum. Alternatively things like ozone and water vapor can perhaps be measured by observing reflected solar energy: that is the solar energy reflected from the earth in the ultra-violet to measure ozone and perhaps in the near infra-red to measure the spatial water vapor distribution. Radars may be mounted on satellites although some improvement in the present radar capability will be necessary for world wide coverage. Storm locations in some parts of the atmosphere may be detected by measuring sferics. Meteorologists will also be interested in measuring the variable X-ray, ultra-violet and particle emissions from the sun. Meteor particles will also be of interest to meteorologists since they may serve as freezing nuclei in cloud and precipitation formation. Many other measurements such as the observation of the optical properties of the earth's atmosphere will doubtless be attempted in time.

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