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South African Solar Radiation Survey 1937-38.

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AN INVESTIGATION ENDOWED BY Dr. H. MERENSKY.

FOREWORD.

In 1935 my attention was drawn to the fact that one of the members of the scientific staff of the Jena University Institute of Physical Therapeutics was making investigations on the solar radiation in Kenya. As lack of knowledge regarding this subject in South Africa was a serious deficiency in our public health armamentarium the opportunity was seized for getting some information on the matter. We had long realised that we were woefully ignorant of the nature and value of our sunlight and of its possible influence on human, plant and animal life and health. Miss Riemerschmid, the worker in question was, therefore, invited by the Union Government to extend her tour to the South. She was fortunately able to spend some months in the Union taking readings, more particularly at the Nelspoort Tuberculosis Sanatorium and near the site in Durban where the Government was about to erect the King George V Tuberculosis Hospital.

These preliminary investigations revealed striking information. It appeared that our sunlight had greater therapeutic value than that at some of the best-known health resorts of the world. It became more than ever desirable that exact information regarding these rays should be obtained.

The money available for health work in the Union was limited. For abstruse investigations of this kind none could be made available while other more immediately pressing health needs could not be met. It was at this point where Dr. Hans Merensky became aware of the interesting findings of Miss Riemerschmid. After ascertaining the value that a more complete investigation would have for health and other workers in the Union he volunteered to bear the whole cost of a survey extending over a year, it being understood that the Government would then continue to survey for such further period as would be necessary to supply the data required. The present valuable report by Miss Riemerschmid is the direct results of Dr. Merensky's munificence. The work is to continue for a further five years with the costly instruments purchased by Dr. Merensky for Miss Riemerschmid's initial survey. Deep gratitude goes out from the many workers on problems of applied biology in South Africa to the man whose generosity made this investigation possible.

E. H. CLUVER,

Formerly Secretary for Public Health.

ACKNOWLEDGMENT.

In order to carry out the investigations of the Solar Radiation Survey, 1937/38, the co-operation of a number of interested persons and bodies was secured and in this connection the Department of Public Health is particularly indebted to the following:—

1. Drs. J. Daneel, H. L. Murray and J. Meyer, Rietfontein Hospital.
2. Mr. H. E. Wood, Union Observatory, Johannesburg.
3. Dr. D. H. Pfeiffer and Mr. M. Brennan, Tempe Isolation Hospital, Bloemfontein.
4. Dr. T. S. Paraskevopoulos and Mr. E. Steyn, Boyden Station of Harvard College Observatory, Mazelspoort, Bloemfontein.
5. Dr. H. R. Ackermann, Nelspoort Sanatorium.
6. Dr. J. Jackson and Mr. J. Driver, Royal Observatory, Cape of Good Hope, Cape Town.
7. Dr. D. L. Ferguson and Mr. B. J. Buckley, Health Department, Port Elizabeth Municipality.
8. Mr. S. A. Engelbrecht, Meteorological Office, Durban Aerodrome.
9. Professor H. H. Paine and Mr. M. Roberts, Physics Department of the Witwatersrand University, Johannesburg.
10. Dr. T. E. W. Schumann and Mr. B. R. Schulze, Meteorological Office, Irrigation Department, Pretoria.
11. Mr. H. Coblans, Natal University College, Durban.
12. Messrs. C. M. van Wyk and J. G. van der Wath, Onderstepoort Laboratories.
13. Messrs. W. Zunckel and R. B. Naylor, Natal National Park Hostel.

A. INTRODUCTION.

Tropical and sub-tropical countries where people of European races have come to settle permanently and where animals of European origin have been introduced, present a large number of climatological problems. The climate appears to have many influences, the effects of which can hardly be traced in the white population. Amongst animals, however, particularly in those which carry a high infusion of the blood of European breeds, the difficulty of maintaining themselves successfully in terms of European health and function standards, is apparent. Any investigations likely to improve our knowledge and understanding of these events are of utmost importance, particularly in a country like South Africa, where a possible detrimental influence of the climate is fully realized.

It has long been known, that solar radiation is one of the most potent of all climatic forces affecting organic life. Relatively little research work has as yet been done regarding the influence of solar radiation on human, plant and animal life and function, except in respect of the therapeutic value of the sun's rays in combating human diseases such as tuberculosis, rickets and others. South Africa, however, offers a great variety of problems connected with its abundant sunshine, which can only be studied on the basis of accurate physical measurements of this energy.

Dr. H. Merensky, who realized that the collection of such data on a large scale alone could help to solve many of these problems, decided to sponsor a Solar Radiation Survey in the Union of South Africa, for which he gave a generous grant to the Public Health Department. The grant of £5,000 provided the necessary instruments, staff salaries, travelling and incidental expenses for the period 1937/38.

The work of carrying out the Survey was entrusted to the author. Dr. J. Grober, Professor of Clinical Medicine at Jena University, who is recognised as an authority on acclimatisation, came to the Union to give his advice in respect to the planning of the Survey.

The measurements were carried out at six stations in the Union during the period from July 1937 to June 1938. Whereas in European countries climatic and meteorological conditions vary within small areas, the climate of South Africa is fairly even over large tracts and hence it was possible to survey the solar radiation throughout the country using comparatively few stations.

The results obtained at the six Solar Radiation Stations in the Union during the Survey 1937/38 are discussed in detail in this report.

B. THE AIM OF THE SURVEY.

To study the influence of solar radiation upon organic life a knowledge of the prevailing radiation conditions is a fundamental requirement. Such a foundation includes a knowledge of the exact amounts of radiation orginating from the sun which reach the earth at various places and at various times of the day and year, of the variation in quality of the rays and of the quantities of specific bands of the solar spectrum.

The Solar Radiation Survey, 1937/38, adopted the collection of such data as its *first aim*, and the account given below presents the results of certain physical measurements taken during this period at six stations in the Union.

The *second aim* was to correlate and co-ordinate the solar radiation data with meteorological and climatological factors as far as they influence bionomics. This aim may be summed up in terms of a bioclimatological research. Data pertaining to such a research in the Union were also collected during the 1937/38 survey. They consisted of cooling temperature readings and qualitative measurements of the solar radiation.

The *third aim* of the survey follows from the first two indicated above. It is to determine as accurately as possible, in quantity and quality, the physical energy necessary to cause certain biological reactions.

These three aims follow from various biological problems, examples of which may briefly be indicated here: —

1. *Medical.*—Suppose, for instance, a sanatorium or health resort is planned. The results of the bioclimatological survey could be used to determine a suitable area in which to erect the building and they would, together with meteorological data, indicate the climatic conditions to which the inmates would be exposed. Again, if it is necessary to expose a patient to sunlight, the doctor in charge should be guided by the readings of the intensity and quality of the sunlight in order to prescribe the correct dosage.

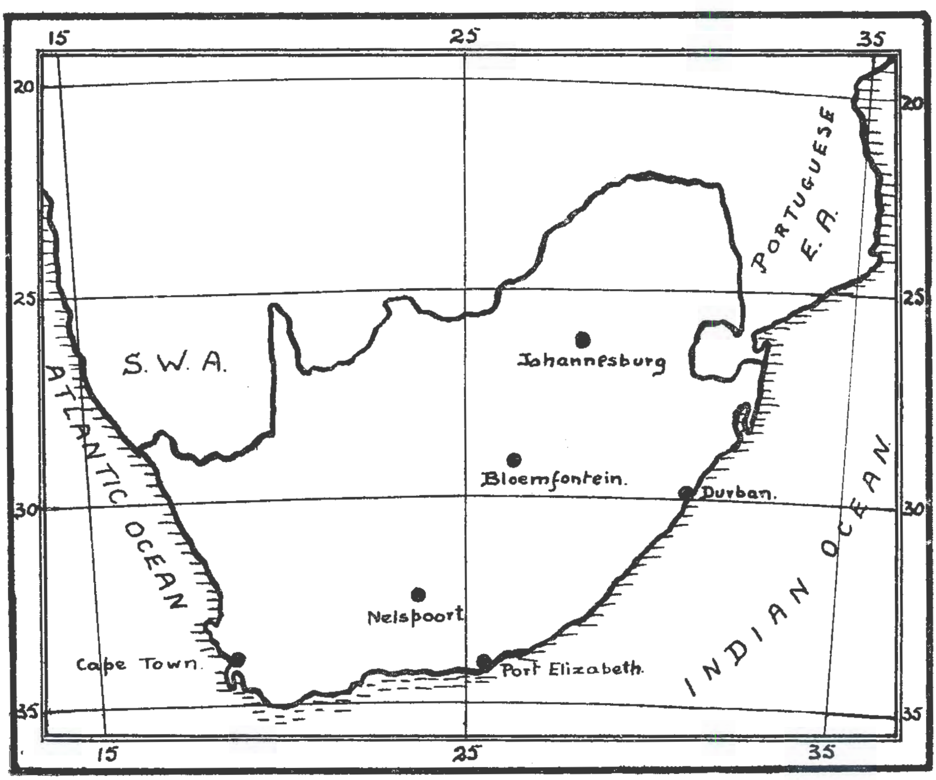
2. *Veterinary.*—Most domestic animals are inclined to seek shade during day-time. The question whether they do this because of excessive solar radiation and whether any adverse effect of the radiation can be prevented to a certain extent by providing shade, is worthy of study. A thorough knowledge of South African sunlight —whether it is stronger than or different in quality from the radiation experienced in the country of origin of the exogenous breeds—is essential for this kind of research. Closely allied to this will be the measurement of bioclimatological factors in areas of the Union where the detrimental influence of environment on livestock is marked and comparing them with measurements from other areas where deterioration is not apparent. Further, to indicate the scope of the work undertaken, one of the many problems connected with the third aim of the survey may be cited i.e. the correlation of physical energies with certain resulting biological reactions. The determination of solar radiation which causes lesions in the skin of sheep infected with the disease known as " geeldikkop " form the basis on which to study and possibly find a remedy for this serious disease.

3. *Botanical.*—It is quite evident that botanical science also offers many interesting problems connected with bioclimatological research. The mechanism of photosynthesis, the conservation of water, date and abundance of flowering, foliar shooting and ripening and many other functions are widely influenced by the total radiation impinging upon plants. A knowledge of this energy, its reduction by the cover of vegetation etc. is of prime importance for botanical research.

The above problems together with many others entail the investigations of every aspect of the bioclimate simultaneously with biological experiments. However, it must be admitted that the methods of measuring the " bioclimate " are not yet so far developed as to enable us to determine every factor which may cause a physiological reaction. Another difficulty is to separate the various components of both the bioclimate and of the physiological reaction. One reaction may result from a number of bioclimatological factors and *vice versa.* Nevertheless it seems vital to determine and correlate as many of these bioclimatological quantities as are possible with the available methods, particularly in a country like South Africa with its abundant sunshine.

It is obvious that the greatest value of any bioclimatological research can be achieved only by close collaboration between the bioclimatologist and the biologist, since they will help to avoid any faulty interpretation of each other's results.

As mentioned before, the Solar Radiation Survey, 1937/38, concentrated more particularly on collecting fundamental data in order to obtain a knowledge of the prevailing radiation and bioclimatological conditions in various areas of the Union.



Sketch Map of the Union of South Africa showing the Six Solar Radiation Stations.

The chapter which follows deals with the significance and purpose of the measurements carried out, and demonstrates how they have been used during the Survey 1937/38 for research work in collaboration with scientific institutions. This is followed by a chapter on the technique of the measurements. Finally the results of the radiation and cooling temperature measurements are presented separately and compared with overseas data.

C. MEASUREMENTS CARRIED OUT DURING THE PERIOD JULY, 1937, TO JUNE, 1938, AND THEIR SIGNIFICANCE.

The Secretary for Public Health, Dr. E. H. Cluver, in close collaboration with Dr. J. Grober of Jena University, decided which areas in the Union would be of greatest interest from a bioclimatological and a public health point of view. The observation stations were erected at Government hospitals within these areas, wherever convenient arrangements could be made. If circumstances were unfavourable more suitable sites were chosen at other institutions.

During May and June, 1937, the six stations were established at the following centres:—

Inland Stations
- I. Johannesburg, Rietfontein Hospital.
- II. Bloemfontein, Tempe Isolation Hospital.
- III. Nelspoort Sanatorium (Karroo).

Coastal Stations
- IV. Durban, Aerodrome.
- V. Port Elizabeth, Lady Donkin Isolation Hospital
- VI. Cape Town, Royal Observatory.

(See sketch map on page 347.)

In order to secure simultaneous readings from these six stations without having specially trained observers, self-registering instruments were used.

From July 1st, 1937, the self-recording instruments were in operation at the six Solar Radiation Stations. Apart from some unavoidable interruptions they registered continuously until June 30th, 1938 and after the completion of the survey the instruments were carefully checked to make sure that their sensitivity had not changed.

In accordance with the threefold aim of the survey it was decided that the following measurements would best serve the purposes of such a survey in South Africa:—

1. Measurements to ascertain the quantity of the total solar energy impinging at various places in the Union.
2. Measurements of the quality of the sun's rays, particularly of the biologisally effective ultraviolet radiation.
3. Measurements of the cooling temperature conditions in the various climatic areas.
4. Specific measurements for the purposes of biological experiments in medicine, veterinary science and botany.

1. Measurements to Ascertain the Quantity of the Total Solar Energy Impinging at Various Places in the Union.

(a) *The daily, monthly and yearly amount of sun and sky radiation.*

The total solar radiation emitted from the sun is reduced on its way through the atmosphere. This reduction depends on the geographical situation of a given place, on its altitude above sea-level and on the cloudiness and the turbidity of the atmosphere.

The comparison of the intensity on various days, the mean values for the various months and the fluctuations from these mean values are important in assessing the biological values of the climate in different parts of the Union.

The total solar energy impinging on a horizontal surface was therefore measured at the six Solar Radiation Stations. Hereafter this intensity is called the "*total amount of sun and sky radiation*" as it is composed of the direct sunlight plus the scattered radiation from the sky.

Cloudiness and turbidity vary with the meteorological conditions. An extremely cloudy month will show a relatively small amount of solar energy which does not necessarily correspond with the amount prevailing during the same month in *other* years. It is therefore necessary to eliminate these contingencies by collecting the data over a period of many years to ascertain what amount of energy is normally active in the various climatic and geographical areas of the Union.

(b) *The Intensity of Sun and Sky Radiation at a Given Time.*

Besides the total amount of sun and sky radiation it is important to determine *the intensity of the solar radiation at a given time.* If, for instance, a doctor intends to expose a patient to solar radiation he has to consider its intensity because local meteorological conditions influence this intensity from day to day. It is essential to *measure* it and to estimate the dose of this physical energy just as accurately as the chemical constituents of any medicine are estimated and prescribed.

The graphs on which the total amount of sun and sky radiation is registered make it possible to read the intensity of the solar radiation at any given moment and enable the doctor to determine the correct dose to which he must expose his patient.

2. Measurements of the Quality of Solar Radiation.

(a) *The red and yellow part of the spectrum.*

The quality of the solar radiation is of importance because the *effect* of any given amount of radiation depends on the quality. An analysis of the sun's light can be achieved by utilizing various filters which permit only light of certain wavelengths to pass. In this way the percentage of red, yellow and other visible rays in the total solar spectrum may be determined.

(b) The Ultraviolet Solar Radiation.

Of all solar rays which reach the surface of the earth, the ultraviolet rays are of great interest as it has been proved by experiments that various specific biological reactions are due to these rays. The most important of these effects are, the bactericidal effect, the changing of ergosterol in the human skin into vitamin D, the erythema effect, the pigmenting effect and the stimulating influence on the metabolism. It is essential in any biological research with which radiation investigations are correlated to estimate accurately the ultraviolet component of the sunshine. Such investigations can either be used in trying to prevent the harmful influence of excessive ultraviolet light (e.g. sunbathing) or they can also be applied by utilizing the beneficial effects of the sunlight for the treatment of diseases.

Comparing South African conditions with those of Switzerland there are two outstanding factors which enhance the climate at the famous health resort in Switzerland. Firstly, there is the altitude above sea-level. In this respect very large areas in the Union have an altitude similar to Davos (Switzerland), which is situated 4,680 feet above sea-level. Secondly, there is the relatively clear atmosphere, which allows a greater amount of ultraviolet radiation to penetrate. It is very interesting to know, therefore, how the intensity of the ultraviolet radiation in South Africa compares with that in Switzerland. This question was made the subject of specific investigations carried out in collaboration with the Solar Radiation Survey 1937/38. There can be no doubt about the importance of such measurements from the public health point of view in fostering the *correct* use of the abundant South African sunshine for the benefit of the population. Equally important is the use of the data of ultraviolet light intensity for biological research on animals and plants.

It may be mentioned here that not only the ultraviolet *solar* radiation, but also the ultraviolet light from the *sky* must be taken into consideration, because the latter is sometimes far in excess of the ultraviolet radiation of the sun alone. Knowing this, a doctor can often eliminate the harmful influence of heat which a patient would get in direct sunlight by exposing him only to the scattered ultraviolet radiation from the sky.

It is quite obvious that only controlled application of ultraviolet light can improve our knowledge of the harmful or beneficial influence of this energy. Readings of the *ultraviolet sun and sky radiation* should therefore always be taken at the time of exposure of patients in order to estimate the proper therapeutic dose at that given time. Careful dosage is particularly important, as an overdose of ultraviolet radiation can result in acute harm.

3. Measurements of the Cooling Temperature.

Apart from the radiation there are other factors influencing the living organism when exposed to the "climate", namely air temperature and wind. These two factors are most important, as they are always present and cannot be eliminated during exposure to the sunlight. They have therefore to be taken into consideration when studying the effect of the bioclimate on living matter. It is, however, very difficult to estimate the combined influence of radiation, wind and air temperature because measurements of that kind depend entirely on the physical qualities of the absorbing body. A hairy coat of an animal, for instance, is quite different in its physical make-up from the smooth skin of a naked human body and will therefore react in a different way to the same physical influences. Consequently the qualities of the measuring instrument, designed to measure a living body's reactions to climatic conditionsfi must be as similar as possible to the physical qualities of the living organism in order that both may react in the same way.

This problem has so far only been solved in the case of the human body. Doctors in Switzerland and Germany, realising the importance of the combined influences of radiation, wind and air temperature, carried out exhaustive studies which resulted in the development of an instrument, the so-called " cooling ball " which represents the human body. The surface temperature of the ball varies according to the cooling or heating effect of the climate and is (within certain limits) equal to the mean skin temperature of the human body. The cooling temperature therefore is a measure indicating the strain of atmospheric conditions on the resting naked human organism. The relationship between physiological strain and cooling temperature was thoroughly studied and the stresses and strains on the heat regulating mechanism of the human body determined. It was found that the least physiological strain occurs at a cooling temperature of 37° C. If the cooling temperature is less than 37° the strain increases because the body is forced to restrict its skin circulation together with the " perspiratio insensibili " and to increase the oxidation. When the cooling temperature is more than 37°, then the body is exposed to stress by overheating. This is, however, automatically controlled by increased perspiration.

It is obvious that the main *practical* value of cooling temperature readings is the correct use of climatic forces in the treatment of human beings. The successful application was proved in one of the children's hospital for surgical tuberculosis on the coast of the North Sea. The dosage of exposure for every one of the 200 children is given strictly according to the readings of the cooling temperature and measurements of the ultraviolet solar radiation. In this way the therapeutic value of the climate was utilized to the utmost.

There is, however, another significance of the cooling temperature readings. It is evident and has to be emphasized over and over again, that the readings cannot be applied to any other living organism except the human being. On the other hand cooling temperature data are for the time being the only " units " which are based on physiological considerations. Bearing in mind, that they represent the physiological conditions of a human organism, the data collected in various areas have a distinct bioclimatological significance in so far as they give well-defined, comparable figures of the combined climatic influences of radiation, air temperature and wind. In this respect they are more closely connected with the actual climatic influences on any living organism than any one of the meteorological data. The variation of the cooling temperature from hour to hour, from day to day and season to season represents a very important physiological factor of the climate.

The cooling temperature was registered continuously at the six Solar Radiation Station in the Union. As the readings taken were not at the time supposed to be used for practical purposes of dosage, the balls were erected at open sites next to the radiation instruments.

4. Measurements for the Purpose of Biological Research.

In addition to the survey of the solar radiation and the cooling temperature throughout the country, the study of problems connected with solar radiation was taken up in collaboration with various Institutions in the Union, the results of which are published separately. It may be of interest, however, to indicate which problems have been investigated in order to show how the measurements of the Solar Radiation Survey 1937/38 have been used for practical purposes.

(*a*) *Stellenbosch, Physics Department of the University.*

Dr. G. D. B. de Villiers investigated the climate of Stellenbosch with special reference to delayed foliation of deciduous fruit trees. Previous investigations had suggested that certain injuries on peach twigs were possibly due to light. Dr. de Villiers therefore concentrated on measuring the ultraviolet intensity of solar radiation to find out whether the ultraviolet was responsible for this injury.

(*b*) *Frankenwald, Ecological Research Station of the Witwatersrand University.*

Miss Margaret Matheson, M.Sc., took readings of the total amount of sun and sky radiation in the open and under cover of grass. At the same time the temperature of the soil at different depths was measured to study the influence of grass on soil temperature and light intensity.

(*c*) *Rietfontein Hospital near Johannesburg.*

Mr. S. J. Richards, M.Sc., working under the supervision of Professor Paine, Department of Physics of the Witwatersrand University, took measurements of the extreme ultraviolet solar radiation. His investigations give us information on the total intensity of ultraviolet radiation and its variation during the different seasons; they also show how this total intensity is composed of sun and sky radiation and how the relation of both varies with the days and the seasons. Furthermore the results obtained were compared with those obtained in various parts of the world.

(*d*) *Onderstepoort Veterinary Research Institute.*

Investigation of a serious disease in sheep, Geeldikkop, had shown that the skin of white sheep became photosensitive under the influence of plant poisoning. When such poisoned sheep were kept in a dark stable they remained unaffected, but as soon as they were exposed to the sun's rays, serious lesions, obviously caused by the solar radiation, were noticed.

Measurements of the quality and intensity of the different parts of the solar spectrum were carried out at the same time as photosensitised sheep were exposed for experimental purposes. It was expected that the exposure of the sheep's skin under various filters would help in the determination of the wave-lengths of the harmful rays and thereby assist in finding methods for the protection of the sheep against these rays. It is obvious that this type of investigation is of economic value to the farmers in the areas concerned.

D. THE INSTRUMENTS AND THE TECHNIQUE OF THE MEASUREMENTS.

It is necessary to give a short description of the various instruments used and of the physical methods employed in the collection of the data given in this report. Reference will also be made to the instrumnets used for direct observations on the ultraviolet light at Stellenbosch and Rietfontein.

1. *Pyranometers and Solarimeters for Measuring the Total Amount of Sun and Sky Radiation.*

The total amount of sun and sky radiation was measured with three pyranometers and three solarimeters.

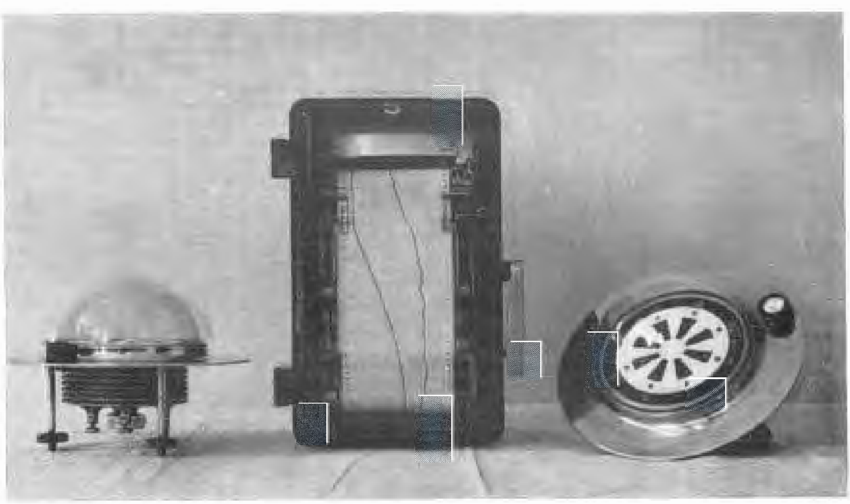


Fig. 1.—Pyranometers and a self-recording Galvanometer.

Pyranometers.—The physical principle on which these instruments work is, that if two wires of different metals are joined to complete a circuit and if one junction is raised to a higher temperature than the other, an electric current flows in the circuit. The strength of this current is proportional to the temperature difference of the two junctions.

The surface of the pyranometer contains several such junctions, an arrangement which is called a thermopile. The alternate junctions are covered with a dull black and a white powder. The black parts absorb the radiation energy and become heated up; the white spots reflect it and remain cool. The difference in temperature of the black and the white parts of the surface of the pyranometer produces an electrical current proportional to the amount of radiation. This current is registered on a graph by a self-recording galvanometer. This instrument is calibrated in such a way that the readings on the graph indicates directly the calories impinging during one minute on one square centimetre of a horizontal surface.

Solarimeters.—The principle on which the solarimeters work is practically the same as that of the pyranometers. The only difference is that, in the case of the solarimeters, only the so-called hot junctions are exposed to the sunlight, and the cold junctions are covered and kept at air temperature. The current produced in the solarimeter is also proportional to the light intensity and the readings on the graph give calories per square centimetre per minute.

The thermopiles in both instruments are exposed horizontally to the sun and sky radiation. They are left in the open continuously and are protected against rain by glass hemispheres.

The pyranometers and solarimeters are connected up with the self-recording instruments by waterproof cables. The galvanometers have to be protected against weather conditions and are therefore kept in a house. The length of the cables permits the radiation instruments to be erected at some distance from the house. The instruments are very reliable when kept in good order, and require about ten minutes attention every day. The accuracy of the readings is within the limit of error of 10 per cent. at the utmost.

The main advantage of using pyranometers or solarimeters in connection with a self-recording galvanometer is the collecting of continuous readings. Although these readings do not indicate the *quality* of sun and sky radiation, they provide the fundamental data for a bio-climatological survey, i.e., the total *quantity* of sun and sky radiation. This intensity is registered on a graph every minute. The mean value of sixty readings gives the average amount of radiation during one hour. From these hourly averages the total daily, monthly and yearly amounts are calculated. In all, 700,000 figures were dealt with during the survey 1937/38.

2. *The "Panzer Actinometer" and the "Michelson Actinometer" for Measuring the Total Energy and Energies of Various Spectral Regions of the Solar Radiation.*

The Panzer Actinometer is also provided with a thermopile and works on the same principle as the Solarimeter. The main difference is, that with the Actinometer the thermopile is fixed at the bottom of a brass tube which is directed towards the sun and which allows only the direct rays from the sun to strike the thermopile. Attached to the tube is an arrangement whereby different filters can be put in front of the thermopile. These filters enable the intensities of the solar rays in different regions of the spectrum to be measured.

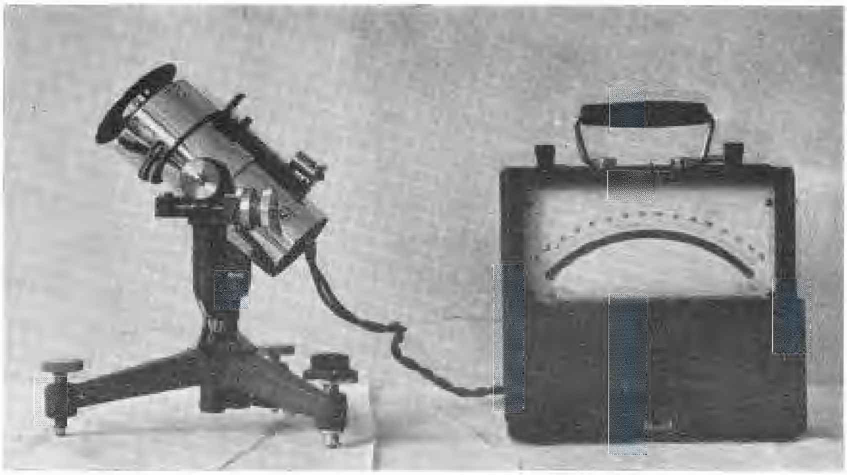


Fig. 2.—The " Panzer Actinometer ".

The filters used were the so-called " Potsdam Normal Filters " which are officially recognised by the " Comité International de la Lumière ". During the Solar Radiation Survey of 1937/38 two filters were used, namely the filter " RG 2 " and " OG 1 ". The former measures the red part of the radiation down to the wave-length 623 mμ, and the latter measures the red and the yellow part of the spectrum down to the wave-length 524 mμ. By means of these readings it is possible to determine the percentage intensity of red and yellow rays in the total amount of solar radiation obtained.

The Panzer Actinometer is a very reliable instrument. Its limit of error is 1-2 per cent. For field work the Panzer Actinometer is connected to a portable galvanometer and shows the correct readings about twenty seconds after being exposed to the sun. The readings of the galvanometer are converted into calories by means of a factor which depends on the temperature of the instrument. As it only takes about two minutes to take a reading and work out the result, this instrument could be used for fieldwork in which the intensity of the solar radiation is needed at any given moment.

The " Michelson-Büttner " Actinometer also measures the intensity of the direct total sunlight and of the various parts of the spectrum.

The principle on which the Michelson Actinometer is based is the following:—The sunlight acts on a bimetallic strip consisting of two different metals, fixed rigidly together. The two metals have different coefficients of expansion and if exposed to the sun's rays the strips will bend. The curvature is proportional to the sunlight intensity impinging on the surface of the strips. This curvature is observed through a microscope with a transparent scale. The readings can be converted into calories per square centimetre per minute by means of a temperature factor.

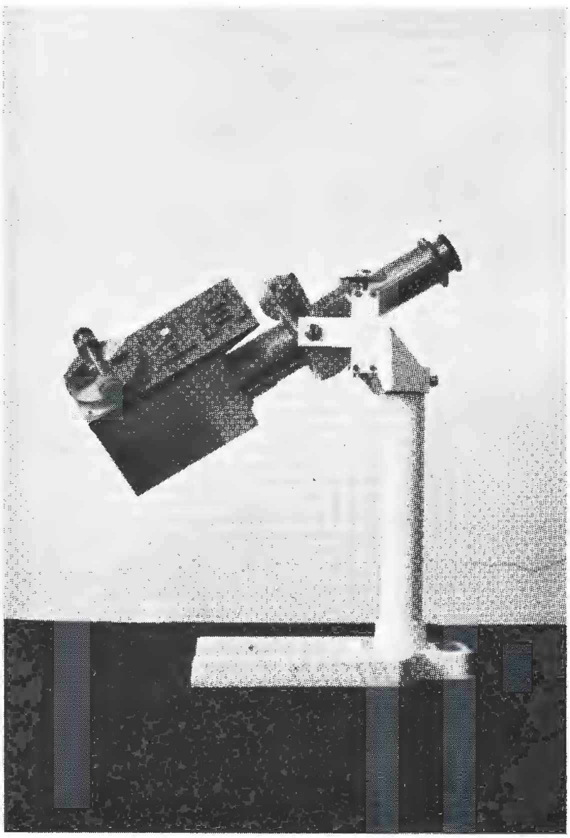


Fig. 3.—The " Michelson Actinometer ".

The Michelson Actinometer is not quite as accurate as the Panzer Actinometer. It is however very suitable for fieldwork, as it consists of a single instrument without appendages and can be used without a table or stand. Its greatest disadvantage is that it is difficult to read under windy conditions. This instrument can also be used with filters.

3. *The " Ultraviolet Dosimeter " for Measuring the Ultraviolet Radiation.*

The sensitivity of the ultraviolet dosimeter to the various rays of the sun's light is similar to that of the human skin. Measurements with the ultraviolet dosimeter are therefore particularly valuable for estimating dosage in heliotherapy. The readings obtained represent the erythema value of the solar radiation.

The ultraviolet dosimeter works on a colorimetric principle. A chemical solution, which is contained in a quartz tube, is exposed for 1-3 minutes to solar radiation. Under the influence of the ultraviolet light, this solution changes its colour from colourless to red. The amount of reddening of the solution is determined by a colour comparison method. The readings are then converted into ultraviolet units by means of a temperature factor. It requires about five minutes for the exposure to solar radiation, reading and working out the result.

Fig. 4.—The Ultraviolet Dosimeter.

The manufacturers had great difficulty in improving this method to permit the readings to be comparable under different temperature and light conditions. This difficulty has now been overcome.

4. *The Cadmium Cells for Measuring the Short-Wave Ultraviolet Radiation.*

The physical principle underlying the measurement of radiation by means of a cell is the fact that certain metals emit electrons under the influence of light. The number of electrons emitted is proportional to the amount of incident radiation. A one-string electrometer is used for measuring the current produced by these electrons. Cadmium cells are used for measuring the ultraviolet radiation in preference to any others.

As with the ultraviolet dosimeters, the main difficulty with the cells was to create instruments exactly alike in their sensitivity to the various rays of the ultraviolet region of the spectrum. The response of the metallic layer in the cell to the slightest difference

Fig. 5.—Cadmium Cells for measuring the direct ultraviolet solar radiation (connected to the electrometer) and the total ultraviolet sun and sky radiation.

in the spectral composition in the light is great, and only recently has the construction of cadmium cells of equal sensitivity been successfully achieved. Comparative readings hitherto impossible can now be taken with different cells. More details on the method of measurements and the use of the instrument are given by Richards (1939). The method entails rather difficult manipulation and it cannot, therefore, be recommended for general use.

5. *The Cooling Ball for Measuring the Cooling Temperature.*

The cooling ball works on the principle of a resistance thermometer. The resistance of any wire alters with its temperature. This fact makes it possible to measure the temperature by observing the change in the resistance of a wire.

The cooling ball consists of two concentric copper spheres. A thin platinum wire is fixed on the inner surface of the outer copper sphere. The change of resistance of this platinum wire is proportional to the change in temperature of the surface of the ball. This surface is, however, influenced by the outdoor conditions, by air temperature, wind and radiation. The cooling temperature readings therefore represent the surface temperature of the ball under the influence of outdoor conditions.

A constant electric current passes through a heating element inside the inner sphere to give off a constant amount of heat which is equivalent to the heat produced in a resting human body. This heat keeps the surface temperature of the cooling ball at approximately the same level as the average temperature of the skin of the naked human body, when both are exposed to the same conditions

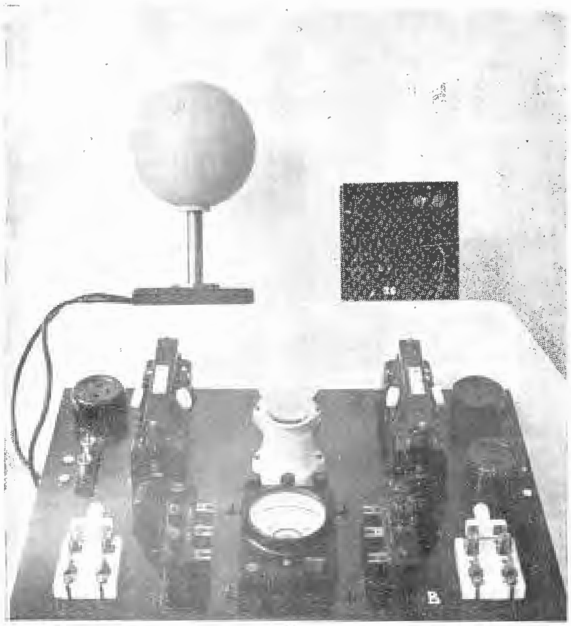


Fig. 6.--Cooling Ball with switchboard and bridge box.

The readings of the cooling ball are registered on the same self-recording galvanometer which is used for the radiation measurements. For this purpose the galvanometer is provided with two independent circuits. The cooling temperature is registered every minute in between the radiation readings. The surface temperature of the ball is given in degrees Centigrade. The graphs are worked out by reading a mean value of the cooling temperature for each hour.

In Fig. 1 (page 353) one of the graphs with solar radiation intensity and cooling temperature tracings can be seen inside the self-recording galvanometer. The graph shows the readings recorded on a clear afternoon. The left line presents the intensity of sun and sky radiation from noon (bottom of the graph) until after sunset, the right line shows the cooling temperature measurements for the same period.

E. RESULTS OF THE RADIATION MEASUREMENTS.

1. *The Radiation at* **Johannesburg.**

(*a*) *General Remarks.*

The geographical situation of the Solar Radiation Station at Rietfontein Hospital near Johannesburg is 28° 04′ E. longitude and 26° 12′ S. latitude. The instruments of the survey were set up on an open space beyond the tuberculosis ward of the hospital. They were fixed on a pillar 4 feet above the ground. The horizon was, unfortunately, not quite clear. Trees shaded the instruments in the early morning and late afternoon hours during part of the year.

Before referring to the climatic conditions at Johannesburg in particular, it is advisable to give extracts from an article entitled "The Climate of South Africa" by the Chief Meteorologist, appearing in the "Handbook for Farmers in South Africa". This will facilitate the understanding of the climatic events which occur during the seasons. It also clarifies the terminology.

"In summer on account of the intense heating of the land, a more or less permanent low pressure is established over the centre of South Africa.—During the passage of a high-pressure system along the coast—there is a flow of air from the high pressure towards the low pressure, i.e., from the sea on to the land. This air, coming off a warm ocean, is laden with moisture which is precipitated—against the eastern escarpment and mostly in the form of thunderstorm over the interior."

"In winter, conditions are more or less reversed: due to the more rapid cooling of the land mass relative to the surrounding oceans, a permanent high pressure or anticyclone is established over the land which effectually bars any influx of moisture from the sea.—the wind blows off the land towards the sea."

Referring to Johannesburg in particular again, the significant climatic features are:

In *summer*: low atmospheric pressure; prevailing winds northerly; mean air temperature 68° F. (mean of January, February and March); rains, mostly in the form of thunderstorms; mean cloud amount still less than 5/10 of the sky.

In *winter*: high atmospheric pressure; prevailing winds north-westerly, but almost 40 per cent. of the time calm; mean air temperature 51° F. (mean of June, July and August); very dry atmosphere; very little cloud; at night rapid loss of heat through radiation from the earth to the cloudless sky.

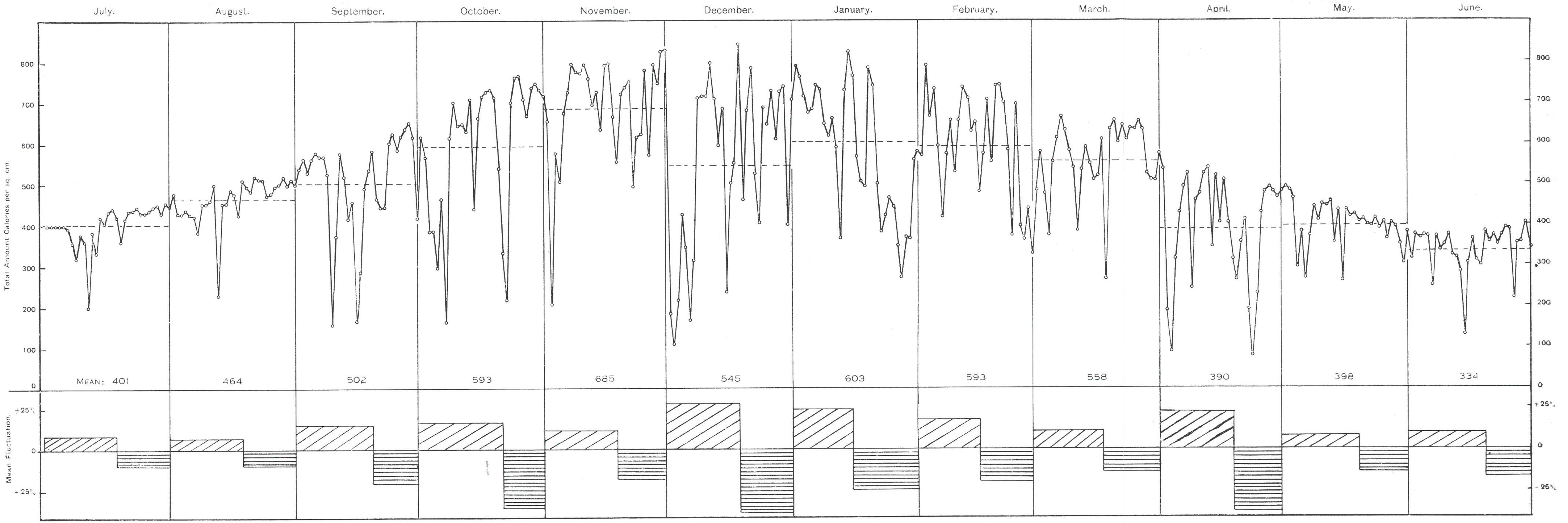
(*b*) *The Total Amount of Sun and Sky Radiation at Johannesburg.*

The intensity of sun and sky radiation was measured with a pyranometer. Graph I shows the total amount of radiation for every day from July, 1937, until June, 1938. The horizontal dotted lines and the figures in each monthly column indicate the mean values for every month.

GRAPH 1.

Johannesburg. Total Daily Amount of Sun and Sky Radiation.

Figures in each monthly column refer to the mean monthly values. Mean fluctuation indicates the amount of fluctuation from the mean monthly amount (See page 365).

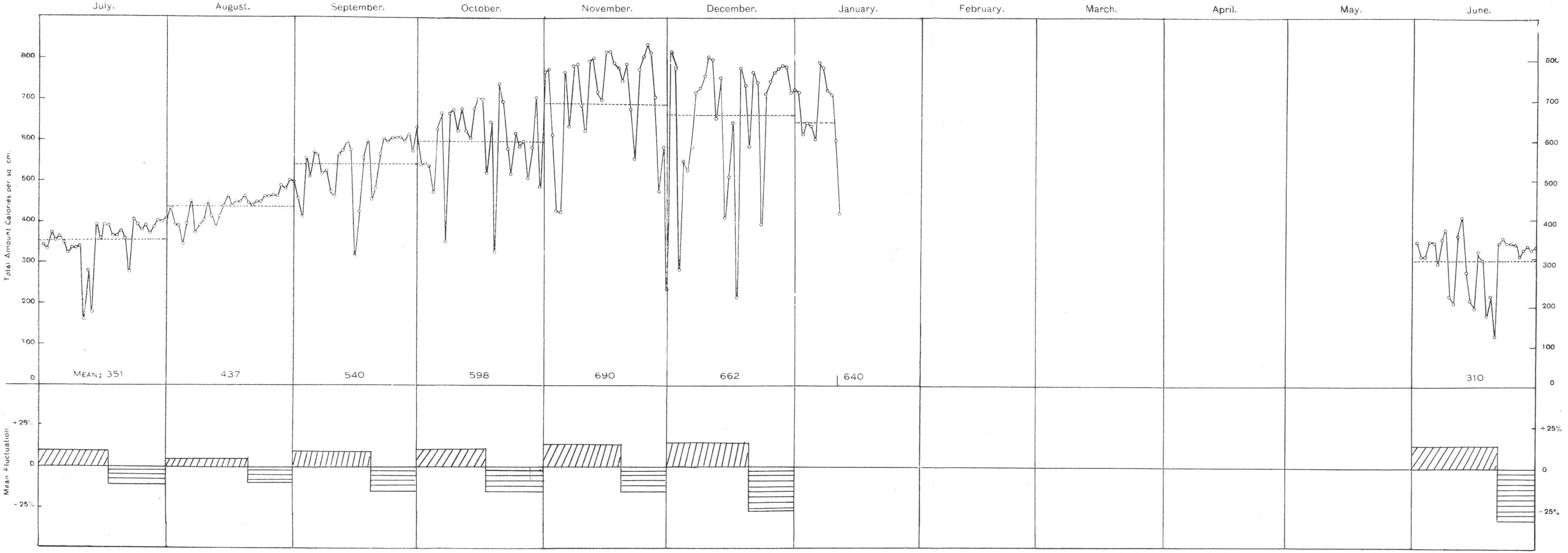


JOHANNESBURG.

GRAPH II.

Bloemfontein. Total Daily Amount of Sun and Sky Radiation.

Figures in each monthly column refer to the mean monthly values. Mean fluctuation indicates the amount of fluctuation from the mean monthly amount (See page 365).



BLOEMFONTEIN.

During July and August, 1937, Johannesburg experienced a steady amount of sun and sky radiation. This was due to the typical winter conditions over the interior. The mean total amount was rather low owing to the low angular altitudes of the sun. In September the period of typical winter weather obviously ceased with the commencement of the rainy season. Nevertheless the total amount of radiation increased rather steadily during September, October and November with the increasing altitude of the sun. November in particular showed a long period of dry weather with a great amount of radiation corresponding to large solar altitudes. December, 1937, had excellent rains and frequent cloudy days which reduced the total amount of radiation markedly. This reduction was quite pronounced until February, 1938, and showed the typical influence of the rainy season. Very frequent cloudy weather over the interior was the main cause of the comparatively small amount of radiation in April. In May and June, 1938, the clear winter weather was very pronounced and again a very steady amount of radiation resulted.

Although the *mean* values for each month are rather significant, it is necessary to consider the fluctuations about these mean values. Radiation far removed from the monthly mean may be more important for the biological events than the mean amount itself. It is analogous to the deviation of the actual monthly rainfall from the mean monthly precipitation.

The graphs of the total amount of sun and sky radiation, therefore, show the number of days on which the fluctuation of the amount of radiation was above (positive) or below (negative) the mean value for the month. It shows this positive and negative amount of fluctuation expressed as a percentage of the mean monthly amount of sun and sky radiation.

In Johannesburg the fluctuation of the amount of radiation about the mean monthly amount was small in winter but large in summer.

2. *The Radiation at* **Bloemfontein.**

(*a*) *General Remarks.*

The Solar Radiation Station was established at Tempe Isolation Hospital, about 5 miles west of Bloemfontein (Long. 20° 13′ E., Lat. 29° 07′ S., 4,500 feet above sea-level).

The significant features of the climate at Bloemfontein are rather similar to those prevailing at Johannesburg (see page 360). They are both situated in the climatic zone of the highveld, a plateau at 4,000 to 6,000 feet above sea-level comprising the northern part of the Cape Province, the Orange Free State and major portions of the Transvaal. On the whole Bloemfontein is appreciably drier than Johannesburg, the annual rainfalls being 20″ and 30″ respectively. The mean air temperature for summer is 72° F., for winter 48° F.