The instruments were erected on an open space near the nurses' home. They were set up on a pillar 4 feet above the ground. Unfortunately one of the instruments broke down in December and could not be repaired until May as spare parts had to be ordered from Europe. Thus measurements of the total amount of sun and sky radiation were only taken from July until December, 1937. In May, 1938, the instruments were transferred to the Boyden Station Observatory and were registering there the following June.

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

As measurements of the total amount of sun and sky radiation are not available for the months January until June, 1938, it is not possible to discuss the main features of the amount of the radiation obtained during the course of the year except for the first six months.

Graph II shows the total amount of sun and sky radiation for every day.

During the period beginning with July and ending with September, fine, cloudless winter weather predominated, resulting in a steadily increasing amount of sun and sky radiation. In October and November, the prevailing influences on the amount of radiation were the altitude of the sun and infrequent cloudy weather, resulting in a further steady increase of intensity. A marked influence on the radiation due to the rainy weather was only noticeable towards the very end of November and during December. This is also shown by the fluctuation from the monthly average amount of sun and sky radiation (see Graph 2).

3. *The Radiation at* **Nelspoort Sanatorium.**

(a) General Remarks.

Nelspoort Sanatorium is situated in the Karroo and in spite of being located on the edge of it, its climate is typical of that area (Long. 23° 01′ E., Lat. 32° 09′ S., 3,319 feet above sea-level).

The instruments were fixed on the roof of the new European ward.

The characteristic features of the climate at Nelspoort are the following: For pressure conditions refer to general remarks on Johannesburg (see page 360).

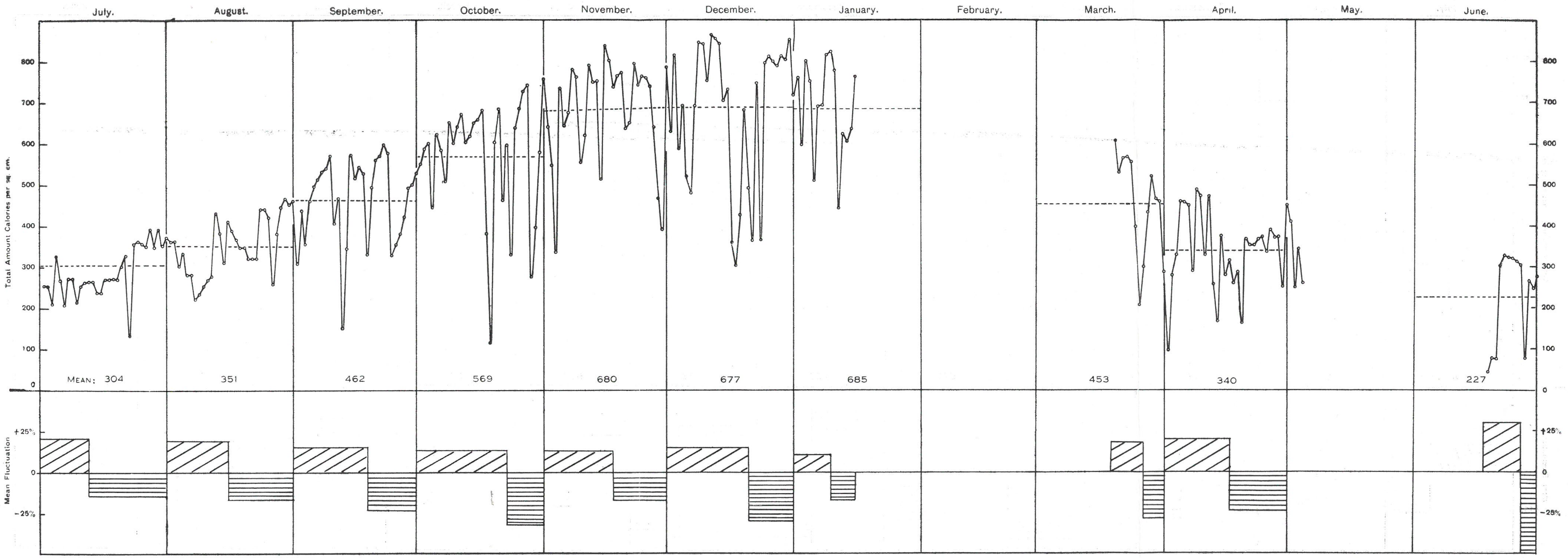
In *summer*: the prevailing wind direction is south-south-east; mean air temperature 73° F. with very marked diurnal fluctuation; low relative humidity; small rainfall and little cloudiness.

In *winter*: prevailing winds from the north to the west sector; mean air temperature 51° F., influenced by the strong incident radiation during daytime and loss of heat through outward radiation at night; extremely dry; almost cloudless skies.

GRAPH III.

Nelspoort. 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).

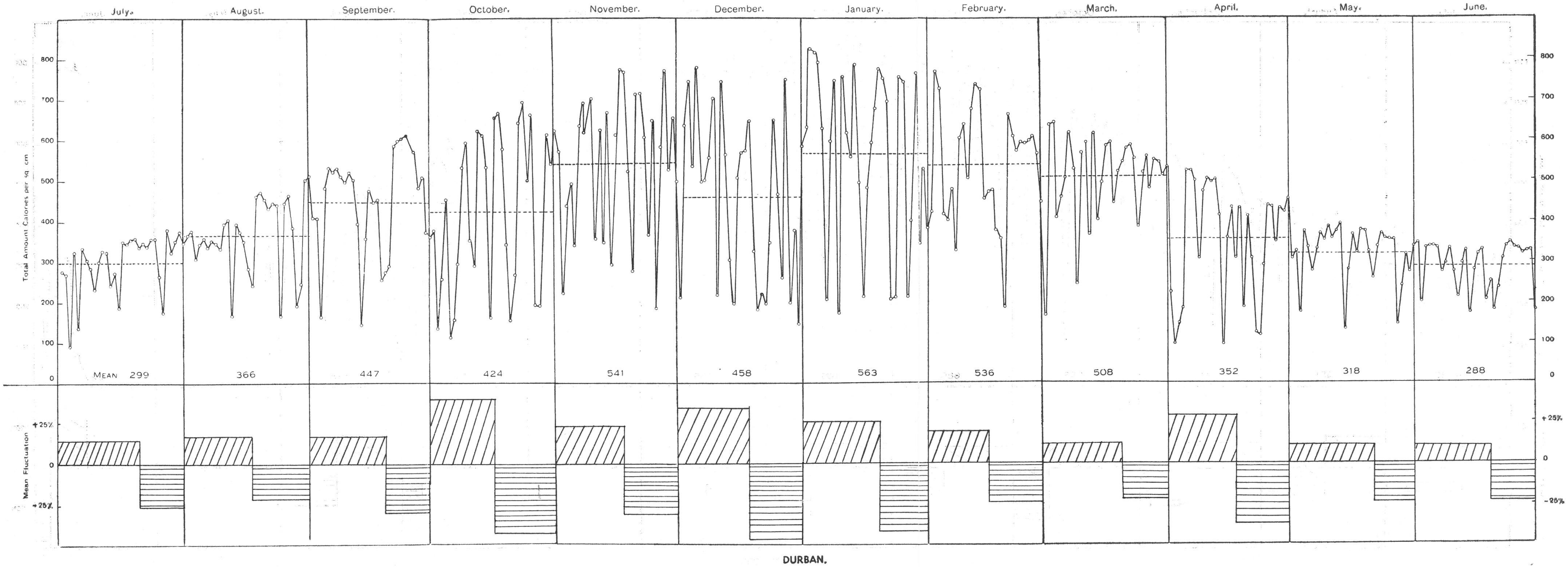


NELSPOORT.

GRAPH IV.

Durban. 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).



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

The total amount of sun and sky radiation is given in Graph III.

Except for a few fairly cloudy days a very steady total amount of sun and sky radiation took place from July until the middle of October, producing a very long period of increasing intensity. Then the influence of the rainy season commenced. The three months, November, December and January had an equal mean amount of radiation with many rather cloudy days; but there were also two clear periods of about 7 days each with over 800 calories per square centimetre per day, which is a very large amount. During the following months measurements were only taken periodically and can therefore not be discussed.

4. *The Radiation at* **Durban.**

(a) *General Remarks.*

The new Tuberculosis Hospital was still under construction and the measurements of the Solar Radiation Survey at Durban were therefore, carried out at the Aerodrome (Long. 31° 03′ E., Lat. 29° 52′ S., 20 feet above sea-level).

The instruments were set up on the roof of the new Aerodrome buildings. The horizon was quite clear except for the Berea ridge shading the instruments shortly before sunset.

The climatic conditions at Durban may be briefly summarised as follows:—

In summer: pressure relatively low; the prevailing winds blow along the coast, either from north-east or from south-west; mean air temperature 75° F.; very humid, the summer being the rainy season; cloud amount usually high especially with south-westerly winds.

In winter: pressure relatively high; winds show a tendency to blow more off the land; mean air temperature 64° F.; humid; still a fair amount of clouds due to proximity to the ocean though much less than in summer.

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

The total amount of sun and sky radiation at Durban is given in Graph IV.

After three months of winter conditions (July, August and September) including several periods of about 10 days when the radiation was practically undisturbed, the beginning of October brought with it the distinct change to summer conditions. The rainy season lasted until February, reducing the radiation considerably. Cloudless days were quite rare. At the end of February there were 8 days of clear weather, followed by another period of decreased sun and sky radiation. This decrease was not as pronounced in

March as in April. Then a change to clear winter weather conditions took place. The amount of radiation was nevertheless not very large because of the low altitude of the sun in winter.

During four winter months, July and August, 1937, and May and June, 1938, the fluctuation from the average monthly amount of sun and sky radiation was small. During the other months the radiation varied considerably from day to day. This fact has to be taken into account as an important factor of the radiation climate at Durban.

5. *The Radiation at* **Port Elizabeth.**

(a) General Remarks.

Port Elizabeth's geographical data are: Long. 25° 37′ E., Lat. 33° 37′ S., 250 feet above sea-level.

The Solar Radiation Station was set up on the grounds of the new Lady Donkin Isolation Hospital. The location of the instruments was not favourable because they were shaded during the early morning and late afternoon by some trees. Nevertheless this place was chosen as it could not be improved upon at any of the other hospitals in that area.

Port Elizabeth, situated on the south coast of the Cape Province, falls in the climatic zone which receives rain in all seasons. Prevailing winds are from the east and west, more or less along the coast; mean air temperature in summer 70° F., in winter 59° F.; in late winter occasionally hot, dry and unpleasant north-westerly winds; cloud amount fairly high throughout the year.

(b) Total Amount of Sun and Sky Radiation at Port Elizabeth.

The total amount of sun and sky radiation, as shown in Graph V, demonstrates the influence of the rains occurring in all season. There was no definite period of uninterrupted radiation as at the inland stations with summer rainfall, nor the clear summer season as in Capetown. On the other hand, partly cloudy days with a large amount of radiation occurred frequently for the reason, that the reflection from the clouds increases the total intensity when the sun shines between white clouds.

There were large and frequent fluctuations from the mean monthly amounts.

6. *The Radiation at* **Capetown.**

(a) General Remarks.

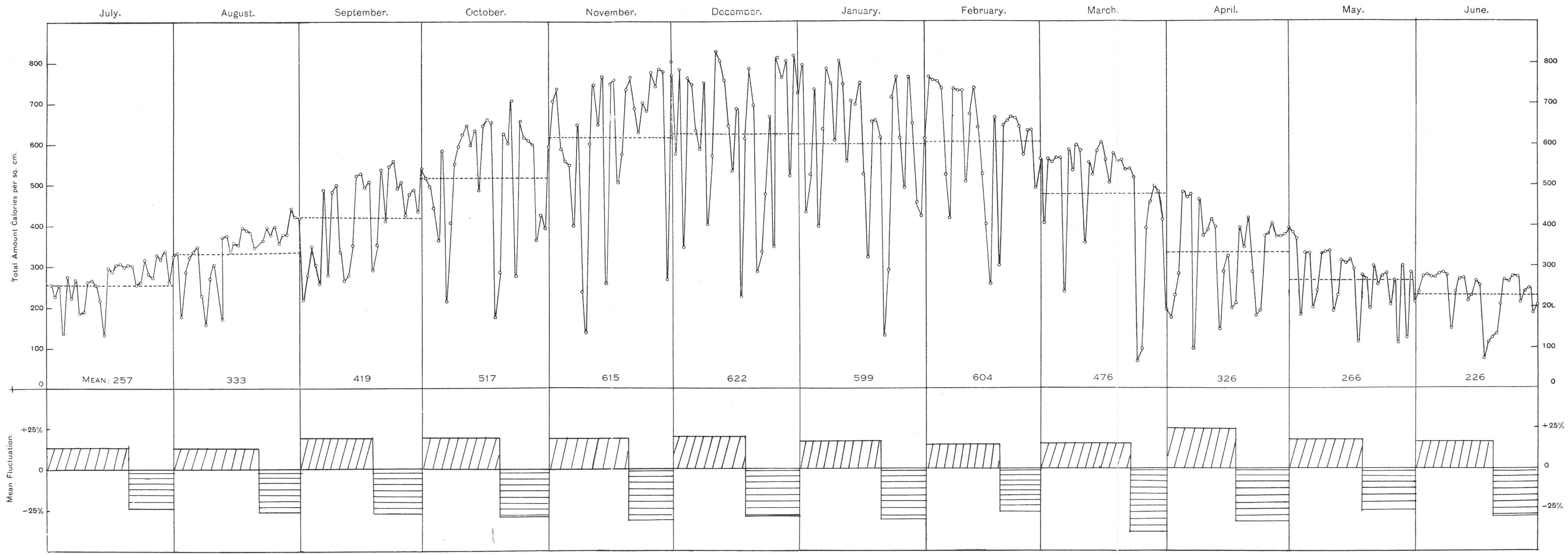
In Capetown the instruments were established at the Royal Observatory (Long. 10° 28′ E., Lat. 33° 56′ S., 40 feet above sea-level).

The instruments were fixed on the roof of the main building, freely exposed to the elements.

GRAPH V.

Port Elizabeth. 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).

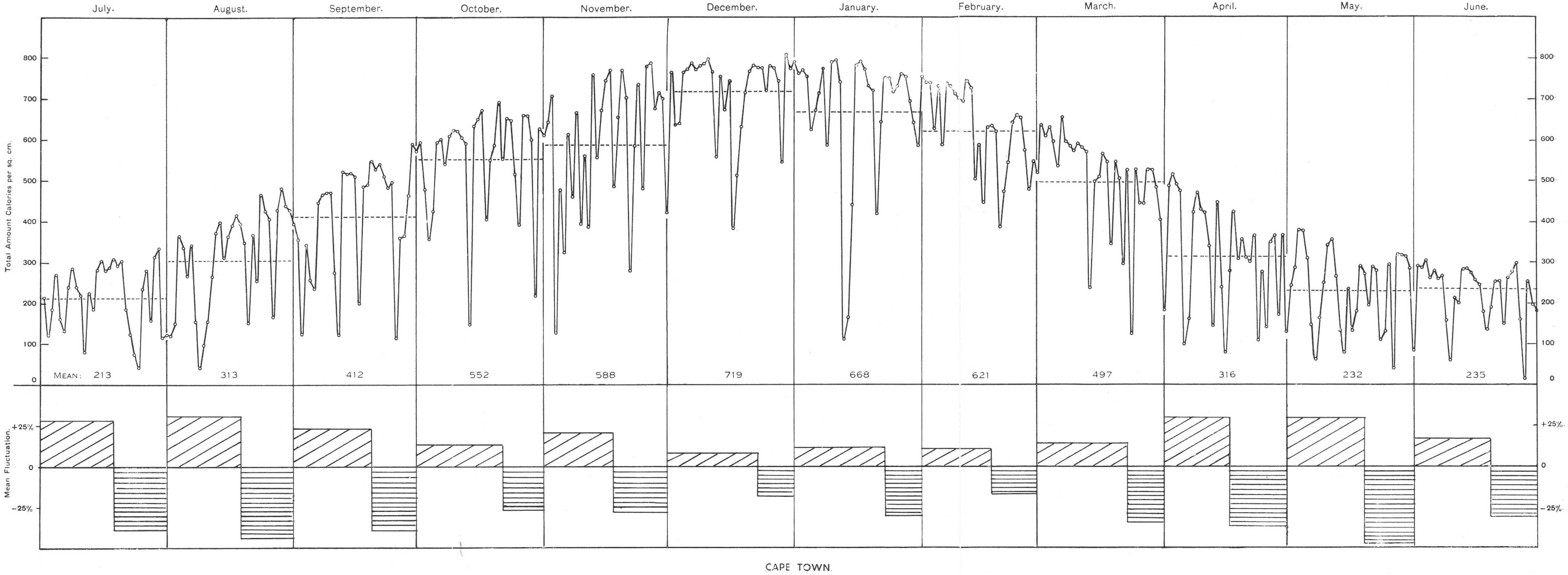


PORT ELIZABETH.

GRAPH VI.

Cape Town. 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).



Important for the conditions prevailing at any particular place in Capetown is its position on either the southern, eastern or northern slopes of Table Mountain, because cloudiness and rainfall are strongly influenced thereby. Thus quite a pronounced variation of these elements exists within a limited area.

The main features of the climate of Capetown are those of the winter rainfall area.

In *summer*: fairly dry and clear weather; winds almost exclusively from the south to south-east; mean air temperature 71° F.; cloud amount fairly low during the midsummer months.

In *winter*: prevailing winds from the south-east and north-west, the latter resulting in cloudy and rainy weather; mean air temperature 56° F.; both humidity and cloud amount high; weather frequently unsettled.

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

The influence of changing weather conditions in Capetown is at once obvious on looking at Graph VI, which shows great variations of the total amount of sun and sky radiation nearly the whole year round. The interruption of fine days by cloudy days reduced the radiation again and again. It is certain that this must be of great importance to biology, particularly to plants, which are exposed to this frequent change of light intensity.

The fluctuation from the monthly mean amount of radiation was very great all the year round.

Another important conclusion which can be drawn from Graph 6 is the fact, that Cape Town was *the* place which received the *greatest monthly amount* of radiation during the period under invesigation. This was due to the fact that the dry summer season coincides with the highest altitudes of the sun. A period of more than six weeks (from the 1st of December until the 12th January), interrupted only by a few cloudy days, brought a daily average amount of 797 calories per square centimetre, a remarkably great intensity.

On the other hand, the influence of cloudy weather was sometimes very great. It reduced the total amount of sun and sky radiation considerably, e.g. while 740 calories were registered on one day (12.1.1938), only 110 calories occurred the next.

The significant features of the total amount of sun and sky radiation in Capetown were:—

(1) A steady increase of the mean total amount with the increase in sun's altitude.

(2) A period of comparatively many bright days with a great amount of radiation from December until the middle of February.

(3) Great fluctuations from the mean total amount during the remaining months.

COMPARISON OF THE TOTAL AMOUNT OF SUN AND SKY RADIATION OBTAINED AT SIX STATIONS IN THE UNION.

1. *Comparison of the Monthly Average Amount.*

The amount of radiation impinging on a horizontal surface at any particular place depends mainly on two factors: firstly, on the altitude of the sun, or in other words on the angle of incidence of the rays, and secondly, on the atmospheric disturbances such as the cloudiness, water vapour content, and amount of dust and other particles in the air.

(*a*) *The Inland Stations.*—Graph VII shows the average monthly amount of sun and sky radiation at the six Solar Radiation Stations in the Union. It indicates that the influence of the sun's altitude was the dominating factor at the inland stations during *the winter months* (July and August 1937 and June 1938). This is proved by the following fact:—

The greatest total amount of radiation during these months was experienced in the most northern station, Johannesburg, where the sun's altitude is greatest. Taking the average amount of radiation for cloudless days only, a comparison of the three inland stations shows, that Johannesburg again received the greatest amount. Next in order was Bloemfontein and then Nelspoort Sanatorium. After August, 1937, the atmospheric disturbances influenced the total amount. Johannesburg no longer experienced more radiation than the other inland stations further south. This refers to the months October and November 1937, when the rainy season was not yet very pronounced. In December and January the sequence of the amount of radiation experienced from the north to the south was opposite to that in winter. Nelspoort had the greatest amount followed by Bloemfontein and then Johannesburg. A comparison for the months February until May, 1938, is unfortunately not possible due to the absence of readings at either Bloemfontein or Nelspoort. In June, 1938, the sequence of the amount of radiation was again from north to south as during the winter months 1937.

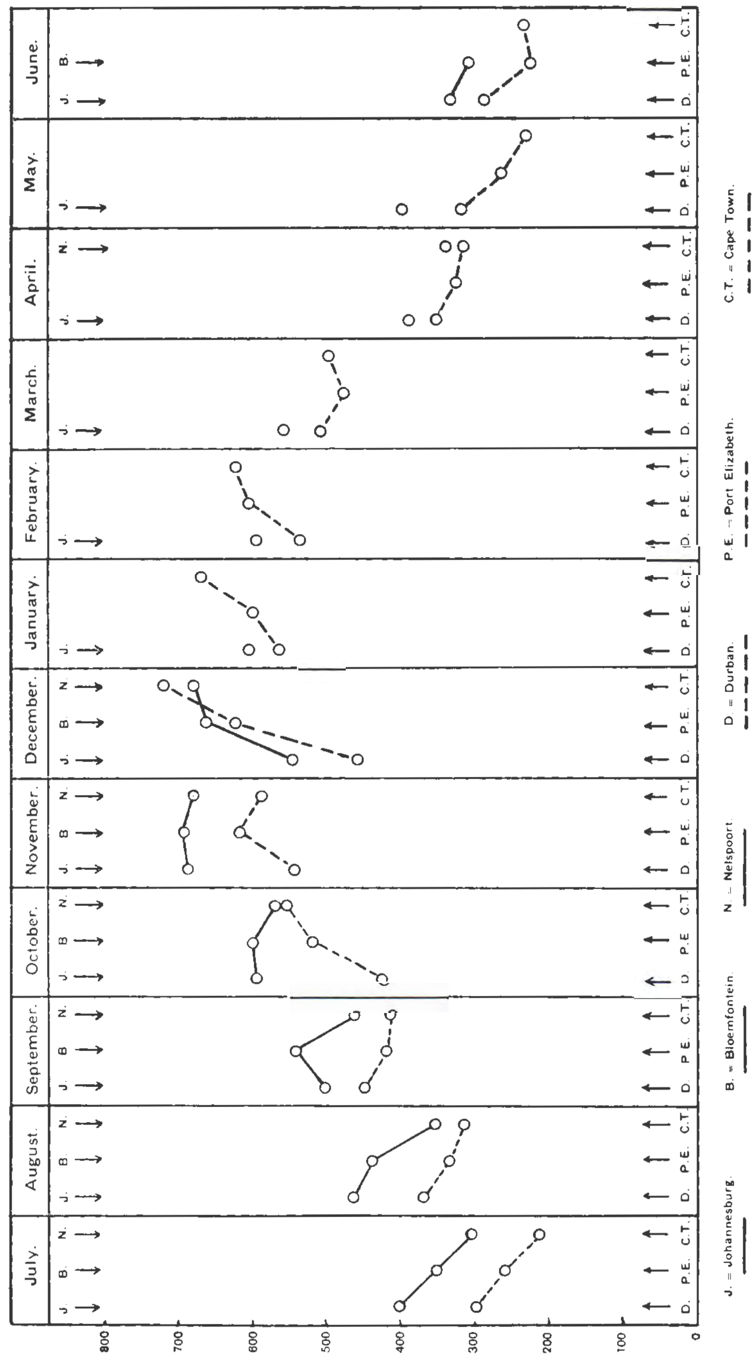
(*b*) *The Coastal Stations.*—Before comparing the results at the the three coastal stations, the following facts have to be emphasized:—

(1) Cape Town and Port Elizabeth are situated at the same latitude, 34° S., which results in an equal altitude of the sun in both places. Thus, as far as the influence of the sun's altitude is concerned, the total amount of radiation in Cape Town and Port Elizabeth should be equal. Any difference in amount must consequently be due to atmospheric conditions.

(2) Cape Town is situated in the small area of pronounced winter rainfall; Port Elizabeth experiences rains more or less the whole year round with no distinct rainy season. Durban, situated at 30° S., lies in the area of summer rains.

GRAPH VII.

Monthly *Average* Amount of Sun and Sky Radiation at Six Stations in the Union.



The results:—

Cape Town and Port Elizabeth experienced a similar amount of radiation all the year round except for two months, namely December and January. During these two months a considerable amount of radiation was recorded at Cape Town where the clear summer season then coincides with the greatest altitudes of the sun. This amount not only exceeded that of Port Elizabeth but was also greater than that at any of the inland stations.

The third coastal station, Durban, had a greater amount of radiation than the other coastal stations from July until September, 1937, and again from March until June, 1938. This applies to the monthly average as well as to the amount obtained on cloudless days. During the rainy season (October until February),however, the reduction of the radiation by clouds was so effective that it could not be compensated for by the greater altitude of the sun in this most northerly coastal station.

(*c*) *Comparison of the Inland and the Coastal Stations.*—Another interesting comparison is that between the amount of radiation registered at Durban and at Bloemfontein, because both are situated at about the same latitude. The approximately equal altitudes of the sun at both stations result in nearly the same angle of incidence of the sun's rays on a horizontal surface. Differences in the amount of radiation were accordingly due only to atmospheric disturbances, i.e. the differences in atmospheric conditions at sea-level (Durban) and at an altitude of 4,500 feet (Bloemfontein).

As far as readings for Bloemfontein are available, a comparison with the Durban readings shows that the amount of radiation at Bloemfontein was always greater than the amount registered at Durban. This result could be expected because of three factors present at Durban:—

(1) The greater amount of cloudiness at the coast.

(2) The reducing influence of smoke and carbon particles in the area of a town and harbour in contrast to clear air conditions at a place like Tempe Isolation Hospital which is situated 5 miles out of Bloemfontein.

(3) The influence of a thicker layer of atmosphere above the sea as compared with the thinner layer above the highveld.

These points are mentioned here to indicate that there are also minor factors influencing the amount of radiation at any particular place, namely the altitude above sea-level and the local atmospheric conditions.

Referring to Graph VII again there is still another result which can clearly be demonstrated from this graph. *The amount of radiation recorded at the inland stations exceeded the amount at the coastal stations practically all the year round.* This is also shown in Table 1, which gives the monthly total amount of sun and sky radiation for the six stations in the Union.

TABLE 1.

Monthly Total Amounts of Sun and Sky Radiation at Six Stations in the Union.

Month.	Johannes-burg.	Bloem-fontein.	Nelspoort.	Durban.	Port Elizabeth.	Cape Town.
July	12,436	10,883	*9,609*	9,262	7,977	*6,614*
August	14,373	13,536	10,872	11,341	10,330	9,686
September	15,052	16,187	13,858	13,409	12,582	12,371
October	18,389	18,525	17,633	13,158	16,031	17,105
November	**20,544**	**20,691**	20,385	16,223	18,451	17,644
December	16,897	20,520	**20,979**	14,186	**19,268**	**22,301**
January	18,087	—	—	**17,451**	18,606	20,698
February	16,604	—	—	14,999	16,919	17,389
March	17,299	—	—	15,733	14,754	15,404
April	11,712	—	10,186	10,559	9,769	9,487
May	12,324	—	—	9,849	8,236	7,187
June	*10,008*	*9,289*	—	*8,645*	*6,777*	6,945

The figures in this table give the total monthly amounts of radiation in calories impinging on one square centimetre of a horizontal surface. The figures in black indicate the greatest amount for each station, the figures in italics show the smallest amount for each station.

The figures in Table 1 are very instructive. They show the following outstanding features during the course of the year:—

The greatest monthly amount of radiation in the Union was obtained by the following stations:—

During—

July and August, 1937	2 months	in Johannesburg.
September, October and November, 1937	3 months	in Bloemfontein.
December, 1937, January and February, 1938	3 months	in Cape Town.
March, April, May and June, 1938	4 months	in Johannesburg.

This shows that during six months of the year under investigation, Johannesburg of all stations, obtained the greatest amount of radiation. But it is also possible that during some of these six months the amount at Bloemfontein may have been greater. During at least three other months Bloemfontein received the greatest amount of radiation.

The distribution of the monthly maximum amounts of radiation obtained in the Union may be summarised as follows:—

> *During nine out of twelve months the greatest amount of radiation was obtained in the climatic zone of the highveld. During the remaining three months (December,* 1937, *January and February,* 1938) *the greatest amount was recorded in Cape Town.*

The smallest amount of radiation in the Union was obtained at the following stations:—

During—

July, August and September, 1937......	3 months	in Cape Town.
October, November, December, 1937, January and February, 1938.........	5 months	in Durban.
March, 1938..........................	1 month	in Port Elizabeth.
April and May, 1938..................	2 months	in Cape Town.
June, 1938...........................	1 month	in Port Elizabeth.

This may be summarized as follows:—

During all the twelve months the smallest amount of radiation was obtained at one or other of the coastal stations. In five of the twelve months Cape Town recorded the least; during five other months Durban received the smallest amount.

It has to be considered, however, that the "greatest" and "smallest" amounts are often not very outstanding, as the differences between the total amounts at the various stations were sometimes relatively small

After discussing the question *where* the greatest and smallest amounts of radiation were measured during the course of the year it is perhaps relevant to consider *when* these values were obtained at the various stations. The figures in Table 1 show that:—

At each station the greatest amount of radiation occurred during the months November or December, 1937. *The smallest amounts were recorded during the months of July,* 1937, *and June,* 1938.

Furthermore it is of interest to compare, at each station, the ratio of the greatest to smallest monthly amount of radiation. These figures are given in Table 2.

TABLE 2.

Differences between the Greatest and the Smallest Monthly Amount of Radiation at Four Stations in the Union.

Name of Station.	Greatest Monthly Amount.	Smallest Monthly Amount.	Ratio.
Johannesburg........................	20,544	10,108	2·1 : 1
Cape Town..........................	22,301	6,614	3·4 : 1
Port Elizabeth......................	19,268	6,777	2·8 : 1
Durban..............................	17,451	8,645	2·0 : 1

The ratios are of particular *biological* interest in botanical and veterinary science because they demonstrate the extremes to which plants and animals are exposed while living in the open all the year round. The figures in Table 2 indicate that:—

> *Johannesburg registered during the month of greatest radiation, twice as much solar energy as it did during the month of lowest radiation. Capetown, Port Elizabeth, and Durban received in the month with maximum radiation respectively 3·4, 2·8 and 2·0 times the amount that was registered during the month with minimum radiation.*

Before concluding the discussion on the monthly total amounts of radiation at the six stations in the Union it is of interest to show their distribution over the year on a graph, as given in Graph 8. Referring to the various stations separately the main features of this graph may be summarised as follows:—

> *The amount of radiation obtained shows, in all six stations, an increase and decrease with the seasons. Johannesburg received a rather irregular amount of radiation during the course of the year. At Bloemfontein and Nelspoort the increase of the monthly amount with the increase of the altitude of the sun was progressive. In Durban great variations of the amount of radiation occurred from month to month. Port Elizabeth showed a very regular distribution over the year. In Capetown the amount also increased and decreased steadily in accordance with the sun's altitude, but showed distinctly high readings in December and January.*

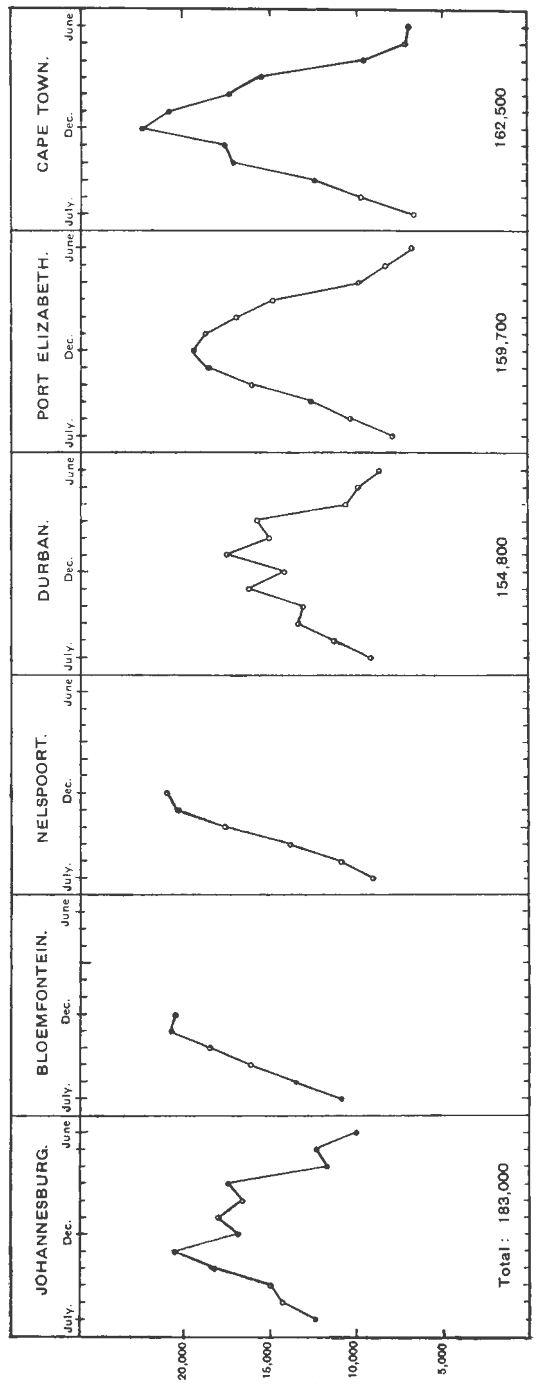
2. *Comparison of Half-Yearly Total Amounts of Sun and Sky Radiation at the Six Stations in the Union.*

The total amount of sun and sky radiation for all six stations is only available for the first half-year of the Solar Radiation Survey 1937/38. Table 3 gives the figures for July until December, 1937 (first half-year) and for January until June, 1938 (second half-year) separately.

TABLE 3.

Yearly Total Amount of Sun and Sky Radiation at Six Stations in the Union.

	INLAND STATIONS.			COASTAL STATIONS.		
	Johannesburg.	Bloemfontein.	Nelspoort.	Durban.	Port Elizabeth.	Cape Town.
First halfyear.....	97,700	100,300	92,700	77,600	84,600	85,700
Second halfyear...	86,000	—	—	77,200	75,000	77,100
Total for the year.	183,700	—	—	154,800	159,600	162,800



GRAPH VIII.

Monthly *Total* Amounts of Sun and Sky Radiation and their Distribution over the Year.

Summarising Table 3 shows the following:—

During the first half-year under investigation the total amount of sun and sky radiation was largest at Bloemfontein, next in amount was that at Johannesburg and then Nelspoort Sanatorium. At the coast, Capetown and Port Elizabeth had an approximately equal amount of radiation. Durban's amount was distinctly smaller, having received 22 per cent. less radiation than Bloemfontein.

The second half-year showed a greater amount at Johannesburg than at the coastal stations. These experienced a fairly equal amount during the period.

The total for the year was distinctly larger at Johannesburg than at the three coastal stations.

3. *Comparison of the Amount of Sun and Sky Radiation at Johannesburg with that at Three Other Places in the World.*

In order to give the reader a better general interpretation of the facts and figures given in the foregoing text it will perhaps be of interest to present a comparison of these results with those obtained at places in other parts of the world. The readings from the following places were chosen for this comparison:—

(1) Johannesburg, South Africa, 5,800 ft., 28° S., readings from July, 1937, to June, 1938.

(2) Nairobi, Kenya, 6,000 ft., 4° S., readings from December, 1934, to May, 1935.

(3) Davos, Switzerland, 4,700 ft., 47° N., readings during the years 1920 and 1921.

(4) Bad Nauheim, Germany, 450 ft., 50° N., readings during the year 1935.

The local conditions of Johannesburg have already been discussed. Nairobi, capital of Kenya, is located on the East African Highlands, about 400 miles from the coast. Davos, the famous health resort in Switzerland, is situated in a wide open mountain valley, and Bad Nauheim, a well known spa in Germany, lies on the north-eastern slopes of the Taunus, a mountain of medium height, and represents an average semi-humid climate at low altitude.

Table 5 gives the monthly average amount of sun and sky radiation for the above-mentioned places.

A comparison of the figures in this table is more significant when considering the conditions mentioned in Table 4.

TABLE 4.

Place.	1. Range of Sun's Culmination.		2. Altitude Above Sea-level.	3. Yearly Average Number of Hours of Daily Sunshine.
	Highest.	Lowest.		
Nairobi	90°	68°	6·000 ft.	6·3 hr.
Johannesburg	87°	33°	5·800 ft.	8·7 hr.
Davos	67°	20°	4·700 ft.	5·6 hr.
Bad Nauheim	62°	16°	450 ft.	3·8 hr.

TABLE 5.

Monthly Average Amount of Sun and Sky Radiation at Johannesburg and Three Other Places in the World.

Month.		Southern Hemisphere.		Month.		Northern Hemisphere.	
		Nairobi.	Johannesburg.			Davos.	Bad Nauheim.
July	Winter.	—	401	January	Winter.	154	57
August		—	464	February		307	124
September		—	502	March		470	304
October	Summer. Half-Year.	—	593	April	Summer. Half-Year.	528	281
November		—	685	May		538	496
December		619	545	June		621	527
January		665	603	July		640	553
February		566	593	August		511	433
March		587	558	September		468	287
April	Winter.	548	390	October	Winter.	358	194
May		403	398	November		191	72
June		—	334	December		141	53
Total for the Year		—	183,700			150,029	103,380

In winter (Southern and Northern hemisphere) the amount of radiation was much larger at *Johannesburg* than at Davos and in the latter again far superior to the amount at Bad Nauheim. In summer the greatest monthly average amount in *Davos* was slightly higher than that at Johannesburg.

Nairobi experienced during practically every month in the period under investigation a greater amount of radiation than the other places. This is mainly due to the greater altitudes of the sun as well as to the fact that very frequently, white cumuli clouds were scattered over the sky, causing a further increase in radiation by reflection.

Bad Nauheim received a very much smaller amount of radiation than Davos and the other places all the year round.

The ratio between the month with the largest and the month with the smallest amount of radiation was 2·0 : 1 at Johannesburg. In Davos is was 4·5 : 1 and in Bad Nauheim 10·4 : 1, which shows distinctly that the difference between summer and winter is very much more pronounced in these two latter places than nearer the equator.

Referring to the *yearly* total amount of sun and sky radiation the figures show that the slightly greater amount at Davos during the two midsummer months compared with Johannesburg does not compensate for the smaller amount during the other months. Taking the yearly total amount at Davos as 100 per cent., Johannesburg received 122 per cent., whilst Bad Nauheim obtained only 69 per cent. It has to be emphasized, however, that Davos does not represent general European conditions. On account of its situation in a high altitude and the clear and frequently cloudless atmosphere over the Alps the radiation in particular is different from that in the lowlands. Bad Nauheim is more likely to represent the general conditions in Europe.

A further interesting item may be stressed, i.e. the yearly average number of hours with sunshine (Table 4). They show very clearly the excessive amount of sunshine in Johannesburg, and the superiority of Davos over Bad Nauheim. The yearly average for London is 3·8 hours of sunshine per day.

These comparisons may briefly be summarised as follows:-

In winter the amount of sun and sky radiation at Johannesburg was distinctly larger than in Davos (Switzerland) at similar altitude above sea-level. It was 5 to 10 times larger than in Bad Nauheim (Germany) at a low altitude above sea-level.

During two months in midsummer the amount at Davos was slightly larger than that during the respective months in Johannesburg.

Nairobi (Kenya) experienced during the six months under investigation a greater amount of radiation than any of the other places mentioned in this comparison.

The ratio between highest summer and lowest winter readings per month was 2·0 : 1 at Johannesburg, 4·5 : 1 at Davos, and 10·4 : 1 at Bad Nauheim.

The yearly total amount at Johannesburg was 122 per cent. of what was received in Davos; Bad Nauheim obtained only 69 per cent. of that amount.

F. THE RESULTS OF THE COOLING TEMPERATURE MEASUREMENTS.

The following chapter deals with the results of the cooling temperature measurements.

It has been mentioned before (see page 351) that the cooling temperature is a well-defined physical unit which is approximately equal to the mean skin temperature of a resting, naked human body exposed in the open and that it indicates the variations of the combined bioclimatic factors of radiation, wind and air temperature.

When studying the bioclimatic conditions of an area it is preferable to examine the detailed figures of the cooling temperature rather than any mean values. On the other hand, the original data collected during the Survey 1937/38 amounted to more than 24,000 hourly readings, an amount of figures which is too unwieldy to be dealt with in this paper. The number of figures was, therefore, reduced in such a way that the characteristic features of the conditions which are of general biologic interest were made apparent by comparatively few figures. The four outstanding items of general biological interest chosen for this are discussed below.

Firstly, there is the average change of the cooling temperature during the days of each month and the change of conditions during the course of the year. These results can be studied by means of the graphs which are given separately for each of the six Solar Radiation Stations. [They are also given in the form of a table (Tables 13 and 13A) (page 419) to make a comparison of the results obtained at the various stations easier.] These graphs were obtained from the original hourly readings by calculating the average values per month for each hour of the day.

The *second* item is the difference between the highest and the lowest average cooling temperature readings. These are of biological interest because they represent the extremes to which the human body may be exposed. These daily ranges are given in Part A of the tables which contain the detailed results of the cooling temperature measurements for each station. Another significant range is that between 6 p.m. and 6 a.m., as this drop represents the conditions during the nights. These data are given together with the *daily* range in Part A of the above-mentioned tables.

The *third* extract of the cooling temperature readings is based on the consideration that biologists are particularly interested in sudden changes of the conditions to which organic life is exposed. The figures which can give information on this point are those which represent the frequency of large and rapid variations of the cooling temperature. A change of 10° or more during a time interval of one hour was considered to be large, that is to say, if the cooling temperature changed by more than 10° during one hour, this hour was counted as being one with a large variation. The total number of hours with such large variations were counted for each month and are given in Part B of the tables, together with the number of days on which these large variations occurred.

The *fourth* detail of cooling temperature measurements which concerns the biologist is the occurrence of periods of hours with very high or very low cooling temperatures. During these hours a great strain would be experienced by a human body if exposed in the open. Careful investigations in Europe have proved that for a cooling temperature above 40° or below 20° the physiological strain to a naked exposed human body would be so great that the danger of overheating or overcooling was imminent. Periods of more than 5 hours with cooling temperatures higher than 40° or lower than 20° were, therefore, counted for each station and the number and average duration of such periods are given in Part C of each table.

In addition to the detailed results given separately for each station, a comparison of the cooling temperature conditions at the six stations in the Union is presented.

The Results of the Cooling Temperature Measurements at each of the Six Stations.

1. *The Cooling Temperature at* **Johannesburg.**

The mean monthly cooling temperature for each hour per day is given in Graph IX (see also Table 13 and 13A, page 419) where the horizontal divisions represent degrees centigrade and the vertical divisions the 24 hours of the day.

During the course of the year a steady increase of the cooling temperature took place from July until November inclusive. December readings, on the other hand, showed a distinct decrease compared with those in November. During both months the night cooling temperatures were nearly the same, but the day readings in December were 7° lower. In January and February the cooling effect of the rains were still noticeable, whilst in March rather high readings were recorded. The approach of winter, coincident with another outbreak of rains, resulted in very low readings during April. During May the night readings were 5° lower than during April.

A. Ranges.—The difference of the daily average curves in winter and summer is at once evident when looking at the graph, the daily range being much greater in winter than in summer. The exact figures are given in Part A of Table 6. It shows that the difference between the highest day- and the lowest night readings was very large all the year round, but particularly so during the winter months, when a clear sky permitted a strong irradiation from the earth at night. During the rainy season clouds frequently prevented this intensive loss of heat from the earth and the average range of the cooling temperature between day and night became smaller. Nevertheless the yearly average range was 18°.

The average drop of the cooling temperature during the nights (given in the second line of Part A of Table 6), was also great except during the rainy season.

TABLE 6.

Johannesburg, Cooling Temperature: (A) Ranges, (B) Frequency of large Variations and (C) Periods with High and Low Values.

	Month.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.
A.	Range highest—lowest hourly mean value....	21°	24°	21°	18°	18°	13°	14°	16°	18°	16°	20°	—
	Range 6 p.m.–6 a.m.)...	7°	10°	9°	8°	7°	3°	4°	6°	7°	6°	7°	—
B.	Total number of hours with variations greater than 10°............	18	22	23	21	37	43	38	33	55	31	31	—
	Number of days on which these variations occurred..............	19	21	19	12	25	20	17	15	27	22	25	—
C.	Average number of hours per day with more than 40° cool. temp........	0	0	6	6	7	6	6·5	5	6·5	6	0	—
	Number of days on which these high cool. temp. were recorded........	0	0	5	7	16	3	6	1	15	2	0	—
	Average number of hours per day with less than 20° cool. temp........	15	13	12	10	6	16	14	9	0	9·5	12	—
	Number of days on which these low cool. temp. were recorded........	24	31	26	7	1	3	1	3	0	13	30	—

B. Variations.—Part B of Table 6 gives for each month the total number of hours during which a variation of cooling temperature of more than 10° was recorded. The fourth line in the table contains the number of days on which these large variations occurred. For instance, in March there were 27 days with 55 jumps. This indicates that on 27 out of the 31 days of this month considerable and rapid variations of the cooling temperature took place, and that quite frequently they occurred more than once during a day. In Johannesburg the number of hours and days with large and rapid variations of the cooling temperature was great during the whole year under investigation with no distinct maximum of occurrence in any season. Another fact, which can not be seen from the figures, is worth while mentioning, namely that during March, 1938, abnormal drops of more than 20° occurred on 4 separate occasions.

C. High and Low Values.—The average number of hours per month with readings above 40° and those below 20° are given in Part C of Table 6. In addition, the number of days on which these outstanding readings were recorded, are indicated. For instance: In September there were 5 days with readings above 40°. During each of these days the high readings occurred on an average for 6 hours. During the same month cooling temperature readings below 20° were registered over average periods of 12 hours on each of 26 days. Outstanding amongst the figures in Part C of Table 6 are those for November and March. We see here that the cooling

GRAPH IX.

Johannesburg. Cooling Temperature.

Each curve shows the average monthly values of the cooling temperature (in degrees Centigrade) for each of the 24 hours per day.