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J. C. FARMAN, M.A.

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R. A. HAMILTON, M.A.

Atmospheric Sciences Division, British Antarctic Survey

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ABSTRACT

THIS paper discusses the radiation measurements made at the Argentine Islands and Halley Bay in the 10-year period, 1963–72. Full details of the instrumentation are given and the calibration of each type of sensor is discussed in detail. The relationship of the derived sensitivities to the International Pyrheliometric Scale is examined.

Limitations of the instruments and recorders are discussed. Full details of the reduction procedures are given and the overall accuracy of the final tabulations of mean hourly values is assessed. The hourly values are too numerous to be published in full but they have been made available elsewhere. Summary tables are presented, giving sums, means and extremes of the measured radiation components over 10-day, monthly and annual periods.

Volcanic dust from the eruption of Mount Agung in 1963 reached these Antarctic stations late in 1963 and caused a four-fold increase in the diffuse radiation, a similar increase in the turbidity and in the attenuation of the direct radiation but only a small decrease in the global radiation. Analysis of the measurements of direct and diffuse radiation shows that the ratio of forward to backward scattering by the volcanic dust is about 20:1. It follows that such dust is unlikely to produce significant climatic changes.

It is also shown that the variation with wave-length of the extinction coefficient of the dust is small, unlike that often assumed for ordinary aerosols. This precludes the possibility of modelling the effects of volcanic dust by using enhanced concentrations of ordinary aerosols.

CONTENTS

I. INTRODUCTION

RADIATION measurements have been made at the Argentine Islands (lat. 65° 15′ S., long. 64° 16′ W.) and at Halley Bay (lat. 75° 31′ S., long. 26° 40′ W.) since 1957. The British Antarctic Survey (formerly Falkland Islands Dependencies Survey) has operated the Argentine Islands station since its inception and took over the Halley Bay station in 1959 from the Royal Society International Geophysical Year Expedition, which had operated the station since its construction in 1956. The results obtained at Halley Bay during the period January 1957–December 1958 have been published by MacDowall (1962).

Initially, continuous recording of global and diffuse short-wave radiation and of net radiation were carried out. Improved net radiation meters were introduced in 1961 and continuous recording of reflected (albedo) radiation commenced in 1962–63. Ångstrom pyrheliometers were introduced in 1962 and have been used for the measurement of direct solar radiation.

Normal routine meteorological measurements, including the continuous recording of the duration of bright sunshine, are carried out at both stations. Measurements of the temperature and humidity of the atmosphere up to a height normally exceeding 15 km. are made daily by radiosondes. In addition, daily measurements of the total amount of ozone are made with a Dobson ozone spectrophotometer.

This paper is concerned mainly with the observations made during the 10-year period 1963–72. It describes the instruments used and discusses their shortcomings, the difficulties encountered and the methods of analysis.

II. THE RADIATION INSTRUMENTS

1. *General*

Continuous records of global, diffuse and reflected solar radiation and of the net radiation are made at both stations. The short-wave sensors are Moll-Gorczynski solarimeters, mounted at a height convenient for maintenance (levelling and cleaning) and the upward-facing instruments have a virtually unobstructed view of the sky (Plate Ia). They are orientated so that the line of hot junctions runs east–west with the longer line of thermojunctions on the poleward side. The sensitivity of a solarimeter is about 10 μV W^{-1} $m.^2$ and its resistance about 10 Ω. The net-radiation sensors are Kew pattern radiation balance meters (R.B.M.s) with sensitivity about 16 μV W^{-1} $m.^2$ and resistance about 150 Ω.

The Cambridge thread recorders used have a sensitivity of about 60 μA for full-scale deflection (50 divisions, 95 mm.) and resistance of about 20 Ω. Series resistors are added to control the overall scale values and varied according to season to make full use of the chart width.

At the Argentine Islands the reflected radiation (albedo) solarimeter is mounted at the end of an arm about 1 m. long, extending from a pipe of about 5 cm. in diameter rigidly fixed into the ice, and about 1 m. above the surface. During the summer some of the snow and ice melts but to no nearer than 15 m. from the instrument. At Halley Bay it is suspended about 1 m. above the ice shelf by wires attached to three poles forming a 5 m. triangle.

Direct solar radiation is measured at both stations using Ångstrom pyrheliometers, the compensating currents of which are read on precision ammeters. These measurements of direct radiation are used for calibrating the solarimeters and, using yellow OGI and red RG2 filters, for turbidity measurements.

At both stations the duration of bright sunshine is measured by two temperate-latitude Campbell-Stokes sunshine recorders, mounted back-to-back along a north–south axis, and suitably modified for use at high latitudes.

At the Argentine Islands, a calibration chamber was constructed in 1962 for the intercomparison of radiation balance meters. This is a wooden structure of cross-section 50 cm. by 50 cm., 350 cm. long and painted matt black inside. At one end is a 500 W lamp and at the other end is a framework holding two R.B.M.s at a distance of 200 cm. from the lamp. About half-way between the lamp and the R.B.M.s, a glass plate absorbs most of the long-wave radiation from the lamp. The output of each R.B.M. is measured with a potentiometer. Measurements are made with each side of each R.B.M. in turn facing the lamp, thus enabling the asymmetry of the R.B.M. to be measured, and finally the two R.B.M.s are interchanged. In 1964 the framework was modified so that solarimeters could be compared in the same way.

2. *Standard of radiation measurements*

Radiation measurements are made on the International Pyrheliometer Scale 1956 (I.P.S.). This is carried to the stations directly by the pyrheliometers calibrated at Stockholm and indirectly by the solarimeters calibrated at Kew. (The transfer from Stockholm to Kew is by pyrheliometer.) The pyrheliometer calibration of the solarimeters at the Antarctic stations provides cross checks and there have also been a number of pyrheliometer intercomparisons which are discussed in this section. Stockholm calibration certificates quote the pyrheliometer constant K (instrument number) in units of mW cm.$^{-2}$ A^{-2}. This practice is followed below but in other sections radiation intensity is quoted in units of W m.$^{-2}$.

During most of the period under study in this paper, the I.P.S. was based, at Stockholm, on Ångstrom pyrheliometer **158** which took part in the International Pyrheliometer Comparisons, IPC I, IPC II and IPC III in 1959, 1964 and 1970. At IPC III, it was found that K(**158**) had decreased by 1·2 per cent since IPC II, from 975 to 963 (W.M.O.–C.I.M.O.–VI, 1973).

The present Kew standard is **583**. It was calibrated at Stockholm in 1968 and took part in IPC III in 1970. The Kew standard for 1966–68 was **562**.

The history of the British Antarctic Survey pyrheliometers is as follows:

551 was calibrated at Stockholm in 1961, was compared with **552** at Kew in 1961 and was in operation at Halley Bay from November 1962 until February 1969 when it was broken.

552 was calibrated at Stockholm in 1961, compared with **551** at Kew in 1961 and was in operation at the Argentine Islands in February 1968 and with **583** at Kew in 1968. In 1969 it was damaged in transit and was re-built and re-calibrated at Stockholm in 1970. It has been in operation at Halley Bay since January 1971. For convenience, this instrument is referred to as **552A** for the earlier period and **552B** for the period since its reconstruction.

580 was calibrated at Stockholm in 1967 and compared with **562** at Kew in 1967. It has been in operation at the Argentine Islands since February 1968.

701 is the British Antarctic Survey sub-standard, originally calibrated at Stockholm in 1968. It was compared in January 1974 with **580** at the Argentine Islands and with **552B** at Halley Bay, and in August 1974 with **583** at Kew.

Table I lists calibration values of the Kew and the British Antarctic Survey pyrheliometers, based on K(**158**) = 975 prior to 1964 and on K(**158**) = 963 after 1966. Table II lists the measured ratios of the pyrheliometer constants when intercomparisons were made and the ratio of the calibration values. In the case of the comparison of **552A** and **583** at Kew in 1968, the difference between the measured and calibration ratios was so large that we concluded that either an error had been made or that **552A** was damaged in transit to Kew. No subsequent measurements were made with **552A** as it was broken soon afterwards.

In Table I are also given the values of the pyrheliometer constants which we have adopted as being most consistent with all the calibrations and intercomparisons. The ratios of the adopted values are given in Table II.

3. *The solarimeters*

a. *General considerations.* The Moll solarimeter has been described and studied extensively by Bener (1951) and is only briefly described here. The receiving surface is 14 pairs of blackened constantan-manganin thermocouples, each of length 5 mm., width 1 mm. and thickness 0·005 mm. One set of the junctions lies along the centre line of the surface, while the remaining junctions are in good thermal contact with the relatively massive supporting posts. The receiving surface, of area about 1·4 cm.^{2}, is blackened and is covered with two concentric hemispherical glass domes of radii about 13 and 23 mm.

The heat absorbed by the receiving surface is dissipated mainly by convection to the inner dome, and less significantly by radiation to the inner dome and conduction to the supports. On account of the loss by convection, an exact mathematical analysis of the heat balance of the solarimeter cannot be made.

b. *The temperature coefficient.* The increase with temperature of the kinematic viscosity of the air causes a negative temperature coefficient of the sensitivity of the solarimeter, despite the positive coefficient of the thermoelectric power of the thermocouples.

TABLE I

PYRHELIOMETER CONSTANTS, *K* (mW cm.$^{-2}$ A^{-2})

Instrument number	*Station*	*Calibrated at*	*Measured values*	*Adopted values*
701	B.A.S. standard	Stockholm 1973	627	627
583	Kew standard since 1968	Stockholm 1967 Carpenteras 1969 Davos 1970 (IPC III)	586 582 586	585
552B	Halley Bay since 1971	Stockholm 1970	579	583
580	Argentine Islands since 1968	Stockholm 1967	576	580
562	Kew standard, 1966–68	Stockholm 1963	563	564
552A	Argentine Islands, 1962–68	Stockholm 1961	1,043	1,045
551	Halley Bay, 1962–69	Stockholm 1961	1,036	1,036

TABLE II

RATIOS OF PYRHELIOMETER CONSTANTS

Instrument number	*Location and date*	*Measured ratio*	*Ratio of calibration*	*Ratio of adopted values*
701/583	Kew 1974	1·074	1·071	1·072
552B/701	Halley Bay 1974	0·933	0·923	0·930
580/701	Argentine Islands 1973	0·929	0·917	0·925
701/158	Stockholm 1973	0·651		0·651
583/158	IPC III 1970	0·608		0·607
552B/158	Stockholm 1970	0·604		0·605
583/562	Kew 1968	1·040	1·041	1·037
552A/583	Kew 1968	(1·825)	1·777	1·786
552A/580	Argentine Islands 1968	1·805	1·801	1·802
562/580	Kew 1967	0·976	0·972	0·973
580/158	Stockholm 1967	0·601		0·602
562/158	Stockholm 1963	0·580		0·581
551/552A	Kew 1961	0·993	0·993	0·991
552A/158	Stockholm 1961	1·075		1·077
551/158	Stockholm 1961	1·068		1·068

We have used the following relation between the sensitivity S_t at temperature t° C and the sensitivity S_{10} at 10° C, which is based on measurements made at Kew (personal communication):

$$S_t / S_{10} = 1 - 1 \cdot 71 \times 10^{-3} (t-10) - 9 \cdot 25 \times 10^{-6} (t-10)^2.$$

c. *Non-linearity of response.* As the intensity of radiation falling on a solarimeter increases, the temperature difference between the thermopile and the inner dome increases, and the heat-transfer coefficient would be expected to increase, causing a decrease in the sensitivity of the solarimeter. Experiments at Kew (personal communication) show that this is the case. The effect is not large, the sensitivity decreasing uniformly by about 4 per cent as the incident radiation increases from 40 to 1,500 W m.$^{-2}$, i.e. a sensitivity coefficient of $2 \cdot 8 \times 10^{-5}$ W^{-1} m.^{2}.

d. *Inclination of the receiving surface.* Solarimeters are calibrated with the receiving surface horizontal and facing upwards. In any other position, and in particular when they are inverted for measuring reflected radiation, we should expect the convection currents to change and therefore that the sensitivity would change with the inclination of the receiving surface. This has been confirmed by Norris (1974), who found that, for a solarimeter of the type used by the British Antarctic Survey, the sensitivity varied in the ratios 1 : 0·98 : 1·10 for the receiving surface horizontal, inverted and vertical, respectively. However, we have not applied a correction to the sensitivities of the reflected solarimeter when used in the inverted position.

e. *Deviation from exact cosine response.* Ideally, when parallel radiation, with intensity I normal to the beam, falls on a solarimeter at an angle of incidence z, the output should be proportional to $I \cos z$. In practice, the response is azimuth (ψ) dependent and shows departures from the cosine dependence on z. We write, for the output, $E = k\, f(z, \psi)\, I \cos z$ and refer to $f(z, \psi)$ as the cosine-response factor. Taking $f(0, \psi) = 1$, k is the sensitivity obtained by normal calibration. In early years, cosine-response tests were often carried out with the receiving surface vertical and so were unreliable. In recent years, however, measurements have been made at Kew with apparatus in which the solarimeter is mounted with the receiving surface horizontal. It has a fixed lamp in the plane of the receiving surface and a pair of mirrors on a rotating arm by means of which the light from the lamp can be reflected on to the solarimeter from any direction. The intensity of radiation available is about 550 W m.$^{-2}$.

Values of the cosine-response factor of two solarimeters for various values of z and 30° intervals of azimuth are given in Table III. For a constant angle of incidence z, the variation with azimuth shows two

TABLE III

COSINE-RESPONSE FACTORS OF TWO SOLARIMETERS

	Instrument number **1008D** *Zenith angle*						*Instrument number* **1551C** *Zenith angle*					
Azimuth	30°	45°	60°	70°	75°	80°	30°	45°	60°	70°	75°	80°
0	1·002	1·007	1·026	1·031	1·042	1·064	1·001	1·001	1·002	1·001	1·000	0·999
30	1·002	1·007	1·026	1·032	1·046	1·069	1·001	1·001	1·004		1·018	1·034
60	1·006	1·014	1·034	1·042	1·067	1·109	1·000	1·003	1·015		1·063	1·109
90	1·009	1·019	1·040	1·048	1·094	1·141	1·000	1·004	1·019	1·051	1·082	1·141
120	1·005	1·014	1·033	1·042	1·066	1·110	1·001	1·002	1·015		1·061	1·108
150	1·002	1·004	1·024	1·032	1·047	1·071	1·000	1·001	1·004		1·018	1·034
180	1·002	1·005	1·023	1·030	1·042	1·065	1·001	1·001	1·002	1·002	1·001	1·000
210	1·002	1·005	1·023	1·031	1·047	1·070	1·001	1·001	1·004		1·017	1·032
240	1·004	1·014	1·034	1·042	1·067	1·111	1·001	1·002	1·016		1·063	1·106
270	1·007	1·017	1·040	1·050	1·094	1·147	1·001	1·004	1·020	1·051	1·082	1·143
300	1·004	1·013	1·034	1·043	1·069	1·114	1·001	1·002	1·015		1·062	1·107
330	1·002	1·006	1·026	1·032	1·046	1·070	1·001	1·001	1·005		1·016	1·030
MEAN	1·004	1·010	1·030	1·038	1·061	1·095	1·001	1·002	1·010		1·040	1·070
MEAN 0–90	1·005	1·013	1·033	1·068	1·087	1·103	1·001	1·003	1·011	1·026	1·041	1·070
RANGE 0–90	0·007	0·012	0·014	0·017	0·052	0·077	0·001	0·003	0·017	0·050	0·082	0·142

maxima at $\psi = 90°$ and at $\psi = 270°$, and two minima at $\psi = 0°$ and at $\psi = 180°$. To a good approximation $f(z, \psi) = f(z, \psi + 180°)$ and the mean of $f(z, \psi)$ over ψ is nearly the mean of $f(z, 0°)$ and $f(z, 90°)$.

The variation of cosine-response factor from one solarimeter to another is illustrated in Table IV which gives the cosine-response factors of five solarimeters for azimuths 0° and 90° at various zenith angles with mean values.

TABLE IV

COSINE-RESPONSE FACTORS OF FIVE SOLARIMETERS

Instrument number	*Zenith angle* 30°	45°	60°	70°	75°	80°
			Azimuth, ψ = 0°			
1008D	1·002	1·007	1·026	1·031	1·042	1·064
1551C	1·001	1·001	1·002	1·001	1·000	0·999
870C	1·004	1·005	1·008	1·021	1·044	1·040
1547C	1·000	1·000	0·997	0·995	0·995	0·994
1230C	0·999	0·994	0·995	0·977	0·981	0·993
MEAN	1·001	1·001	1·006	1·009	1·012	1·018
			Azimuth, ψ = 90°			
1008D	1·009	1·019	1·040	1·048	1·094	1·141
1551C	1·000	1·004	1·019	1·051	1·082	1·141
870C	1·005	1·018	1·032	1·075	1·119	1·180
1547C	1·005	1·016	1·028	1·035	1·053	1·080
1230C	1·000	1·002	1·005	1·021	1·040	1·060
MEAN	1·004	1·012	1·025	1·061	1·077	1·120

The variation of the cosine-response factor with azimuth at large angles of incidence is due to the caustic of the glass dome; when z exceeds 80°, part of the caustic falls on the thermopile giving rise to additional local heating. When the incident radiation is parallel to the strips, this point falls on the cold junctions, and when perpendicular on the hot junctions (Robinson, 1966).

f. *Errors arising from imperfect cosine response.* The imperfect cosine response of a solarimeter causes appreciable errors in the radiation measurements, especially at large solar zenith angles. For measurements of direct radiation, the ratio of the measured to the true value is equal to the cosine-response factor appropriate to the azimuth and zenith distance of the sun. For diffuse radiation, the error depends on the variations of brightness from zenith to horizon. For an isotropic sky (as assumed for the shade-ring correction (see p. 15)), and a solarimeter with cosine response equal to the mean in Table IV, the measured radiation would be too great by a factor 1·013. For a clear sky with a zenith to horizon brightness ratio of 1 : 4, the factor is 1·020, while for an overcast sky with zenith to horizon brightness of 3:1, the factor is 1·010.

The values are for an average solarimeter. Table IV shows considerable variation of cosine-response factor. The observed data are likely to be between 1 and 3 per cent too large. These errors are not trivial but, in view of their complexity and uncertainty, we have made no attempt to correct the routine reduction of mean hourly values. The errors are directly related to the solar zenith angle and the main bodies of the tables are reliable. The wings should be treated with caution. For deriving spot values of radiation intensity at low solar elevation, the corrections cannot be ignored, cf. p. 21.

4. *Intercomparisons of solarimeters at the Argentine Islands*

Solarimeter sensitivities are given in units of μV W^{-1} m.^{2}; to avoid frequent repetition, the units are normally omitted. Solarimeters are referred to in the text by their instrument numbers, with a serial letter which changes with each period of operation between calibrations at Kew, e.g. **870B.** The sensitivity of a solarimeter is given in the form *S*(**870B**) = 11·0.

Five solarimeters are allocated to each station and returned to Kew in regular rotation for inspection. Thus, except during the relief period, there are three solarimeters in field use, and the fourth (the one most recently calibrated at Kew) is held in reserve as a sub-standard. It will go into field use the following year. The fifth is in transit to or from Kew, where it is calibrated, refurbished as necessary, and re-calibrated to become the new sub-standard.

The calibration at Kew is carried out by comparison with the Kew standard solarimeter. Until 1971 this was **1014,** *S*(**1014**) = 11·3, and was then replaced by **3088**, *S*(**3088**) = 11·8. *S*(**1014**) was re-measured in 1974, using *K*(**583**) = 585, and was found to be 11·3.

When the new sub-standard arrives at the Argentine Island, the old sub-standard and the solarimeter to be withdrawn are compared with it, and with one another, in the calibration chamber. Such three-pair intercomparisons show that the accuracy of a chamber comparison is better than ± 0·5 per cent.

Table V gives the results of the comparisons of the sub-standards which took place each summer.

TABLE V

INTERCOMPARISON OF SUB-STANDARD SOLARIMETERS AT THE ARGENTINE ISLANDS

(Sensitivity in μV W^{-1} m.^{2})

Season	*Instrument number of sub-standard solarimeter*		*Kew sensitivity*		*Ratio old/new*		*Adopted sensitivity*		*Ratio*
	Old	*New*	*Old*	*New*	*Kew*	*Measured*	*Old*	*New*	
1965–66	**1230B**	**1551B**	10·7	11·5	0·930	0·938	10·7	11·4	0·939
1966–67	**1551B**	**1550B**	11·5	11·1	1·036	1·015	11·4	11·2	1·018
1967–68	**1550B**	**1186C**	11·1	11·4	0·974	0·987	11·2	11·4	0·982
1968–69	**1186C**	**870C**	11·4	11·2	1·018	1·021*	11·4	11·2	1·018
1969–70	**870C**	**1230C**	11·2	10·9	1·028	1·040	11·2	10·9	1·028
1970–71	**1230C**	**1551C**	10·9	11·5	0·948	0·929	10·9	11·7	0·932
1971–72	**1551C**	**1550C**	11·5	11·1	1·036	1·055	11·7	11·1	1·054
1972–73	**1550C**	**1186D**	11·1	11·6	0·957	0·958	11·1	11·6	0·957
1973–74	**1186D**	**1230D**	11·6	10·9	1·064	1·060	11·6	10·9	1·064

* The ratio of the sensitivity of these solarimeters when measured in October 1969, after instrument **1186C** had been in service as albedo solarimeter since February 1969, was 1·021. This value has been preferred to the incompatible value of 1·035 measured at the time of comparison of sub-standards.

Adopted values have been chosen to fit best the long series of intercomparisons of solarimeters, of which those given in Table V form only a small part. The agreement with the Kew calibration values is good; in only one case, that of **1551C** is the difference greater than 0·1, the accuracy to which the Kew calibration is given. That the means of the adopted and Kew sensitivities are equal shows that the revisions have altered only individual values and have not introduced any secular changes in sensitivity.

Table VI shows the initial and final calibration values of the solarimeters which have been in operation since the introduction of the calibration chamber at the Argentine Islands. The adopted values used at the beginning and end of the period of operation (normally 3 years), and based on the calibration chamber comparisons, are also given.

TABLE VI

INITIAL AND FINAL SENSITIVITIES OF SOLARIMETERS AT THE ARGENTINE ISLANDS

(Sensitivities in μV W^{-1} m.^{2})

Instrument number of solarimeter	*Initial sensitivity*		*Final sensitivity*		*Increase*	
	Kew	*Adopted*	*Kew*	*Adopted*	*Kew*	*Adopted*
1550A	10·9		11·1	10·9	0·2	
870B	11·0	11·1	11·2	11·2	0·2	0·1
1230B	10·7	10·7	10·9	10·8	0·2	0·1
1551B	11·5	11·4	11·5	11·4	0	0
1550B	11·1	11·2	11·2	11·2	0·1	0
1186C	11·4	11·4	11·6	11·5	0·2	0·1
870C	11·2	11·2	11·3	11·2	0·1	0
1230C	10·9	10·9	10·9	11·0	0	0·1
1551C	11·5	11·7	11·7	11·7	0·2	0

The increases of sensitivity during the period of operation are also given. These increases of sensitivity are small, amounting to about 0·1 μV W^{-1} m.^{2} according to the Kew calibration, while the calibration-chamber measurements show only a negligible tendency for increase in sensitivity. We conclude that this type of solarimeter is very stable even in the harsh conditions experienced in Antarctica.

At both stations some intercomparisons between the global and diffuse solarimeters have been carried out by lowering the shade ring of the diffuse solarimeter during periods when the sky is almost clear of cloud. Both solarimeters now measure the global radiation and the ratio of their sensitivities is given by

$$\frac{S_1}{S_2} = \frac{\Omega_1 i(y_1)}{\Omega_2 i(y_2)},$$

where Ω is the total resistance of the appropriate circuit, and $i(y)$ the current passing through the recorder to give deflection y. (The non-linearity implied by the functional notation adopted for i is discussed on p. 17.) If the ratio of the sensitivities is well established, the measurements can be used to verify the circuit parameters.

At the Argentine Islands, these field intercomparisons agree well with the calibration-chamber intercomparisons. At Halley Bay, where there was no calibration chamber in use during the period under discussion, they have been used to check the sensitivities of the solarimeters.

5. *Field calibration of solarimeters*

a. *Method.* The intensity of the direct solar radiation I, at solar zenith angle z, is related to the global radiation G, and the diffuse radiation D, by

$$I \cos z = G - D.$$

If a solarimeter is alternately shaded and unshaded while a series of measurements of I is performed concurrently, the sensitivities of the pyrheliometer and the solarimeter can be compared. The shading is achieved by blocking the direct radiation using a disc held at such a distance that the solid angle subtended at the solarimeter is equal to the acceptance aperture of the pyrheliometer. The measurements are most simple when performed at local apparent noon, when all the quantities are stationary. However, they can be made at any time when conditions are settled enough to allow interpolation between individual measurements to be made with confidence.

Ideally, the output of the solarimeter should be measured with a precision potentiometer, thereby eliminating errors of reading traces and any uncertainties pertaining to the recorder characteristics. This is now the standard practice but it requires that at least two observers are available throughout the measurements. There are many other tasks, such as ozone observations, to be performed in clear and settled conditions, and in the past it was customary to use the routine recording method to evaluate the solarimeter output. In that case, we have

$$S_t I \cos z = \Omega[i(y) - i(y')],$$

where I, $i(y)$ and $i(y')$ are mean values, respectively, of the direct radiation, and of the recorder currents obtained when the solarimeter was unshaded (recording G) and shaded (recording D), Ω is the total resistance in the solarimeter circuit, and S_t is the sensitivity, at temperature t° C, of the solarimeter. As in the previous section, the notation $i(y)$ for recorder current indicates that account is taken of the non-linear characteristic of the recorder (p. 17).

b. *Calibrations at the Argentine Islands.* Prior to the adaptation of the calibration chamber for use with solarimeters, much use was made of the method discussed above. As an illustration, we present in detail the results obtained with **1550A** during the season 1965-66. Fig. 1a shows the initial reduction for sensitivity, open circles indicating observations taken near local apparent noon. The sensitivity of **1550A,** based on calibrations made at Kew, with $\cos z \sim 0 \cdot 75$, may be estimated as $11 \cdot 0 \pm 0 \cdot 1$ for this season. The open circles are in excellent agreement with this value.

The solid circles show signs of systematic error, particularly at the lower values of cos z. The cosine-response factor (p. 6) of this solarimeter is not known in detail. Fig. 1b shows f(75°, ψ) as measured at Kew, and curves for other values of z have been estimated using the data given on p. 6 as a guide. Fig. 1c then shows the result of correcting the sensitivities to $\psi = 0°$. The remaining scatter is almost evenly distributed about the noon values and the mean of the 49 observations is $10 \cdot 98 \pm 0 \cdot 07$.

The mean values of the sensitivities of solarimeters at the Argentine Islands, determined by pyrheliometer in their first and last season of operation, are given in Table VII together with the initial and final Kew calibration values. The mean of the eight comparable values is 11·19 for Kew and 11·15 for the pyrheliometer calibrations. This indicates good agreement between the British Antarctic Survey pyrheliometer standard and the Kew standard, S(**1014**) = 11·3.

c. *Calibrations at Halley Bay.* Only a few calibrations of solarimeter by pyrheliometer were made in each season at Halley Bay and the recorders gave considerable trouble (see p. 17). The sensitivities determined in this way are therefore less reliable than in the case of the Argentine Islands. The mean sensitivities of those solarimeters for which ten or more calibrations were carried out are given in Table VIII, which also gives the initial and final Kew calibration values. These calculations are based on the recorder scale value given on p. 18, i.e. on a scale value invariant in time but which varied with deflection. The overall agreement is satisfactory.

6. *Radiation balance meters*

a. *General.* Three radiation balance meters (R.B.M.) are allocated to each station for use in rotation. On receipt from Kew, an R.B.M. is held for a year as a sub-standard. It is then put into field use for a year, at the end of which it is returned to Kew. There it is calibrated as received, overhauled as necessary and re-calibrated, and returned to the station at the next relief.

Each radiation balance meter consists of a sensitive plate and a blower, and is calibrated as a unit. If a blower fails (as sometimes occurs) and is replaced by a spare blower, there is a measurable but not very serious change in sensitivity.

b. *Mounting.* The radiation balance meters are mounted at about 1 m. above the surface and are raised (or lowered) when the height of the surface changes. At the Argentine Islands, the radiation balance meter

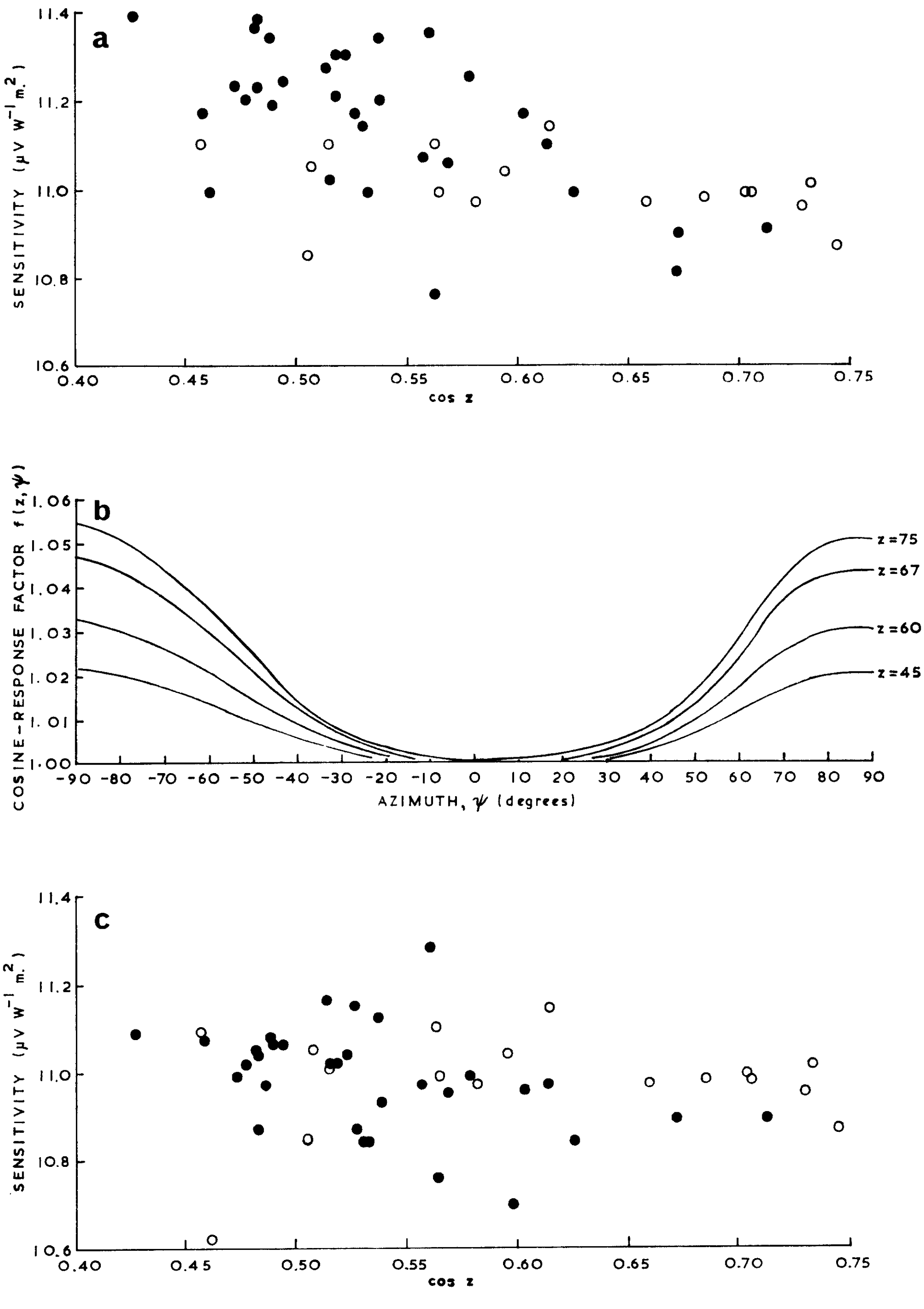

FIGURE 1

a. Sensitivity (at 10° C) of solarimeter **1550A**, 1965–66, uncorrected.

b. Cosine-response factor of solarimeter **1550A**.

c. Sensitivity (at 10° C) of solarimeter **1550A**, 1965–66, corrected to normal incidence.

is positioned above a snow bed, which often becomes wet and dirty in the summer. At Halley Bay, the surface is a snow-covered ice shelf. Notes are made daily on the nature of the snow surface.

The radiation balance meter at the Argentine Islands is adjusted at each major change of wind direction so that the forced draught is down-wind but that at Halley Bay is fixed so that the draught is down-wind for the prevailing wind.

TABLE VII

SENSITIVITIES (μV W^{-1} m.^{2}) OF SOLARIMETERS MEASURED AT KEW AND AT THE ARGENTINE ISLANDS BY PYRHELIOMETER

Instrument number of solarimeter	*Kew calibrations*		*Pyrheliometer calibrations*	
	Initial	*Final*	*Initial*	*Final*
1551A	11·3			11·3
1550A	10·9	11·1		11·0
1186B	11·2	11·2	11·1	11·1
870B	11·0	11·2	11·0	11·2
1230B	10·7	10·9	11·0	
1551B	11·5	11·5	11·4	11·4

Instrument **1551A** was damaged after its period of operation. No pyrheliometer calibrations were carried out on **1551A** and **1550A** early, nor on **1230B** late in their periods of operation.

TABLE VIII

SENSITIVITIES (μV W^{-1} m.^{2}) OF SOLARIMETERS AT HALLEY BAY

Instrument number of solarimeter	*Kew calibration*		*Mean of pyrheliometer calibrations*
	Initial	*Final*	
1028B	12·5	12·5	12·2
1037B	10·2	10·5	10·1
1547B	12·2	12·4	12·5
1008C	10·1	10·3	10·3
1547C	12·4	12·2	12·2
1008D	10·3	10·2	10·3
MEAN	11·28	11·35	11·27

c. *Asymmetry*. Radiation balance meters are asymmetrical to a greater or less extent and thus zero flux does not produce zero output; the importance of this effect is magnified by the high albedo of the snow surface. For, if the sensitivities of the two sides are $S(1+x)$ and $S(1-x)$, where x is the asymmetry, the outputs of the two sides are:

$$S(1+x)\,(G+L\downarrow) \qquad \text{(top side)}$$
$$\text{and } S(1-x)\,(AG+L\uparrow) \qquad \text{(bottom side)},$$

where G is the global short-wave radiation, A the albedo for short-wave radiation, $L\downarrow$ is the downward long-wave radiation from the atmosphere and $L\uparrow$ the upward long-wave radiation from the snow surface.

The net output, therefore, is

$$S\{G(1-A)+L\downarrow -L\uparrow +x[G(1+A)+L\downarrow +L\uparrow]\}.$$

Typical summer values are $L\downarrow = 250$, $L\uparrow = 300$, $G = 500$ W m.$^{-2}$ and $A = 0{\cdot}8$. In this case, the true net radiation is about 50 W m.$^{-2}$ but the apparent net radiation is $50+1{,}450x$. The instrument, therefore, is very sensitive to asymmetry of the two plates. The practice has been to reverse the plates in the middle of each month so that monthly mean values are little affected by asymmetry but individual values will be in error.

The Kew calibration certificates issued since 1965 have included a value of the asymmetry x, and these have varied in the range 0–0·037 with a median value of 0·018. Using this value in the example above, the error introduced by the asymmetry is 26 W m.$^{-2}$, i.e. nearly half the true value.

d. *Temperature coefficient.* The sensitivity of the radiation balance meter increases with temperature; the sensitivity S_t, at temperature t is related to the standard sensitivity S_{10} at 10° C by the following equation which is based on measurements made at Kew (personal communication):

$$S_t/S_{10} = 1+0{\cdot}971\times10^{-3}(t-10)-0{\cdot}157\times10^{-4}(t-10)^2+0{\cdot}134\times10^{-6}(t-10)^3-0{\cdot}167\times10^{-8}(t-10)^4.$$

e. *Calibrations at the Argentine Islands.* During the annual relief it has been possible to carry out inter-comparisons of all three radiation balance meters in pairs, except in 1965–66 and 1967–68 when no comparisons were carried out between the instrument about to be sent to Kew and that which had just arrived. These intercomparisons have enabled us to deduce a logical history of their changes of sensitivity which, as will be seen, fit well into the pattern of Kew calibrations.

The values of the measured ratios of the sensitivities are given in Table IX with the product of the ratios

TABLE IX

RATIO OF THE SENSITIVITIES OF RADIATION BALANCE METERS AT THE ARGENTINE ISLANDS

	Measured ratios				*Kew*	*Accepted ratios*		
Season	O/S	S/N	N/O	*Product*	S/N	O/S	S/N	N/O
1962–63	0·89	1·49	0·78	1·03	1·46	0·89	1·47	0·765
1963–64	1·52	0·605	1·10	1·01	0·605	1·52	0·60	1·10
1964–65	0·66	1·26	1·21	1·01	1·27	0·66	1·25	1·21
1965–66	1·32	1·30	—	—	1·31	1·31	1·32	0·58
1966–67	1·46	0·595	1·15	1·00	0·575	1·46	0·595	1·15
1967–68	0·625	1·17	—	—	1·18	0·625	1·18	1·36
1968–69	1·19	1·51	0·55	0·99	1·60	1·19	1·52	0·55
1969–70	1·52	0·665	0·99	1·00	0·67	1·52	0·665	0·99
1970–71	0·735	1·20	1·14	1·01	1·17	0·725	1·20	1·15
1971–72	1·34	1·35	0·55	0·99	1·34	1·34	1·36	0·55
1972–73	1·57	0·645	0·99	1·00	0·625	1·58	0·64	0·99
1973–74	0·72	1·07	1·31	1·01	1·04	0·72	1·06	1·31
1974–75	0·75	1·12	1·20	1·01	1·11	0·75	1·11	1·20

O Operational. S Sub-standard. N Newly arrived.

which, it will be seen, only once differed from unity by more than 1 per cent. The ratio S/N (Kew) is the ratio of the Kew calibration of the sub-standard to that of the newly arrived instrument. The "accepted" values of the ratios are values so adjusted that the product is unity. From these accepted ratios, adopted sensitivities are calculated for each instrument on arrival, at the end of its period as sub-standard and at the end of its period of operation. These values are given in Table X together with the Kew calibration values. The last two columns of Table X show the increase in sensitivity during the period of operation and the ratio of the final to initial Kew calibration. The change of sensitivity during the period as sub-standard is insignificant.

TABLE X

SENSITIVITIES (μV W^{-1} m.^{2}) OF RADIATION BALANCE METERS AT THE ARGENTINE ISLANDS

Instrument number	*Year of Kew calibration*	*Initial Kew calibration* (K_1)	*On arrival*	*End of* S	*End of* O	*Final Kew calibration* (K_2)	*Year of Kew calibration*	*Ratios* O/S	K_2/K_1
VB2A	1961	18·5	18·7	18·7	19·1	19·1	1964	1·02	1·03
VB3B	1962	12·7	12·6	12·6	13·9	—	1965	1·10	
VB10B	1963	21·0	21·0	21·0	22·0	22·3	1966	1·05	1·06
VB2B	1964	16·4	16·8	16·8	18·7	19·0	1967	1·11	1·16
VB3C	1965	12·7	12·7	12·8	13·4	15·0	1968	1·05	1·18
VB10C	1966	22·0	21·5	21·5	21·7	21·5	1969	1·01	0·98
VB2C	1967	18·7	18·2	18·2	18·6	19·0	1970	1·02	1·02
VB3D	1968	11·7	12·0	12·2	13·3	12·2	1971	1·09	1·04
VB10D	1969	17·4	18·4	18·4	20·6	20·8	1972	1·12	1·20
VB2D	1970	14·9	15·3	15·4	17·8	18·7*	1973		
VB3E	1971	11·1	11·3	11·3	12·7†	12·8	1975	1·12	1·15

* Motor unserviceable; calibrated with another motor and ratio therefore not reliable.
† After 2 years operational service.

In addition to the intercomparisons of the three instruments at the time of ship relief, comparisons between the operational and sub-standard instruments are carried out at intervals during the year. An extra comparison is carried out whenever a blower is replaced. These intermediate comparisons indicate that most of the change in sensitivity takes place in the first part of its period of operational service.

It will be seen that there is a good correspondence between the values in the last two columns; the mean ratio of the initial to final Kew sensitivities is 1·09, while the mean increase of sensitivity during operation of the same R.B.M. is 1·07.

f. *Calibrations at Halley Bay.* There are no similar facilities for intercomparisons of R.B.M.s by lamps at Halley Bay and intercomparisons of two R.B.M.s in sunlight have sometimes given inconsistent results, apparently due to the large effect of asymmetry. In addition, there have been some instrumental failures in operation so that no final Kew calibration could be made.

In most years, however, calibrations have been carried out by measuring the change in net radiation when the upper plate is shaded and comparing this with a simultaneous pyrheliometer measurement of direct solar radiation, thus determining the sensitivity of the upper plate. As the general level of the net radiation is low compared with either the downward or upward components, due to the high albedo of the snow, the shading of the top plate causes a large negative deflection of the recorder which may be off the scale, necessitating the insertion of extra resistance in the circuit.

The results of these calibrations and the Kew calibrations are shown in Table XI with the ratio K_2/K_1 of the final to initial Kew calibration. It can be seen that the values of K_2/K_1 are similar to those at the Argentine Islands and we conclude that the weathering agents are similar at the two stations. There is normally quite good agreement between the pyrheliometer calibration and the Kew values. By assuming that the radiation balance meters undergo the same small changes during transit as shown by the instruments at the Argentine Islands, we have adopted the values shown in the last two columns of Table X as the sensitivities at the beginning and end of each period of operation.

TABLE XI

SENSITIVITIES (μV W^{-1} m.^{2}) OF RADIATION BALANCE METERS AT HALLEY BAY

Instrument number	*Year*	*Initial sensitivity (Kew)* (K_1)	*Pyrheliometer calibration*	*Final sensitivity (Kew)* (K_2)	*Year*	K_2/K_1	*Adopted sensitivity* *Initial*	*Final*
VB10A	1960	21·5		23·5	1963	1·09	21·8	23·0
VB1A*	1961	18·2	21·7	22·0	1965	1·21	20·0	20·0
VB11B	1962	16·0	18·0		1964		16·4	18·0
VB9B†	1963	13·9	14·2		1965		14·0	14·0
VB1B	1964	19·6	20·2	22·4	1967	1·14	19·6	20·8
VB9C	1965	18·8	18·9		1969		19·0	19·0
VB1C	1967	19·4	20·0	19·9	1971	1·03	19·7	19·7
VB9D	1969	12·6	10·5	12·5	1972	0·99	12·5	12·5
7/66A	1970	12·3	12·6	13·6	1973	1·11	12·6	13·4
VB1D	1971	16·6	13·2	19·2	1974	1·16	17·0	18·8

* In operation 16 January–25 April 1963 and again 21 December 1964–8 February 1965.
† In operation 14 June–21 December 1964 only.

III. MEASUREMENT OF DIFFUSE RADIATION

1. *The conventional shade-ring correction*

Both stations use conventional shade rings (C.S.A.G.I, 1958) for shielding the diffuse solarimeters from direct sunlight. In performing this function, such a ring also intercepts a fraction, r, of the diffuse radiation, D^*, so that the radiation incident on the solarimeter is $(1-r)D^*$. If the distribution of sky brightness is $B(z, \psi)$, at zenith distance z and azimuth ψ, the contribution to the diffuse radiation from an elementary (spherical) area at z, ψ is

$$\Delta D = \tfrac{1}{2}B(z, \psi) \sin 2z \, \Delta z \Delta \psi$$

$$\text{and } r = \oint_{\text{SR}} \Delta D \Big/ \oint_{\text{H}} \Delta D,$$

where the surface integrals are over the angles subtended by the shade ring and its support and over the (sky) hemisphere, respectively. The limits of integration for the former are easily expressed as functions of the radius and half-width of the ring, of the latitude and longitude of the station, and of the solar declination (if the ring is correctly aligned). If a specification of $B(z, \psi)$ is available, the evaluation of r is quite straightforward (we have written a computer programme for this purpose). In general, of course, this is not the case.

The conventional treatment is to assume an isotropic sky, $B(z, \psi) =$ constant, and we have conformed to this practice for the routine reduction of the records. We have made some calculations for skies with brightness varying with zenith distance. In overcast conditions, the zenith is usually brighter than the horizon, whereas with clear skies the reverse is the case. We have considered zenith: horizon brightness ratios in the range 3:1 to 1:5. The calculations show that in overcast conditions the conventional corrections will be too large but at worst by 2 per cent, whereas for clear skies they will be too small, at worst by 6 per cent but more probably around 3 per cent.

2A

2. *Some experimental evidence on shade-ring corrections*

The dimensions of shade rings used at the two stations are given in Table XII, together with the maximum values of the conventional correction factors and other parameters discussed below.

TABLE XII

SHADE-RING DIMENSIONS AND OTHER DATA

		Width (mm.)	*Radius* (mm.)	max. $\frac{1}{(1-r)}$	p clear sky	p overcast	*Period of operation*
Argentine Islands	1	24	155	1·096	1·03 (82)	0·99 (14)	To November 1971
	2	50	250	1·126	No obs.	No obs.	From November 1971
Halley Bay	1	26	128	1·136	1·01 (16)	No obs.	To January 1970
	2	27	152	1·115	1·03 (23)	1·00 (4)	January 1970–August 1971
	3	50	250	1·133	1·06 (19)	1·01 (7)	From August 1971

Figures in parentheses indicate number of observations.

a. *Clear-sky conditions.* Some simple measurements have been made at both stations to determine the true correction factors for near cloudless skies. The shade ring was lowered and the solarimeter shaded from direct sunlight by a disc subtending at the thermopile the same solid angle as the acceptance angle of a pyrheliometer. (We adopt this as the best practical definition of the true diffuse radiation D^*.) If D' is the mean of the radiation recorded before and afterwards with the shade ring in position, $D = D'/(1-r)$ is the conventional diffuse radiation and the ratio $p = D^*/D$ is a measure of the error of the conventional factor.

The simplicity of the method, and the advantage that only ratios of chart ordinates are needed, are completely outweighed by the smallness of the effect being sought. A typical ordinate for D' is only about 5 mm. and $D^*-D' \sim 0 \cdot 5$ mm. Individual measurements of p are therefore quite uncertain, by $\pm$ 4 per cent. However, groups of measurements yield interquartile ranges of about 2 per cent in p.

At the Argentine Islands, a large number of measurements was made in 1962–68 in the course of solarimeter calibrations. The median values for each of the summer seasons were:

Season	p	*Season*	p
1962–63	1·03	1965–66	1·03
1963–64	1·05	1966–67	1·04
1964–65	1·03	1967–68	1·03

We note that the apparently high value in 1963–64 coincided with the effects of the dust from the Mount Agung eruption, which caused a prominent aureole around the sun on most clear days in that season.

The median values of p for the different shade rings used are given in Table XII. In view of the uncertainties, the general agreement with the conclusions on p. 15 is satisfying.

b. *Overcast conditions.* When the sky is overcast, all the radiation is diffuse, so that when the shade ring is lowered the diffuse solarimeter measures D^*. The ratio D^*/G is measured at a few points during a period of an hour or two and the ratio D'/G is measured during the period before and after the lowering of the shade ring, and thus $p = (1-r)\ D^*/D'$ can be determined.

The results of these measurements are given in Table XII. They are more reliable than those obtained under clear-sky conditions, since the ordinates are much larger. Nevertheless, errors of 1 per cent or more are possible. To this accuracy, it would seem that overcast skies are adequately represented as isotropic.

Examination of the values of G and D, for overcast conditions, obtained in the routine reduction of the records provides a straight-forward check on the shade-ring correction factor (if the relative scale values are well determined). We have incorporated such a check into our reduction procedure (p. 20). The scatter in $G-D$ for overcast skies confirms the validity of the isotropic approximation to a similar level (± 1 per cent) as above.

Future experimental determination of the shade-ring corrections should be undertaken using precision potentiometers to measure the solarimeter output and a possible systematic variation of the error with zenith angle should be kept in mind.

IV. THE RECORDERS

1. *General description*

The instruments used to record the radiation components are Cambridge thread recorders. They give a full-scale deflection of 50 divisions (95 mm.) for a current of about 60 μA and have a resistance of about 20 Ω. Twin-channel recorders are used for recording the output of the total and diffuse solarimeters at both stations, and of the reflected solarimeter and radiation balance meters at the Argentine Islands. At Halley Bay, these components are measured separately on single-channel recorders.

The recorders are electrically driven and mark a dot on the chart every minute; the twin-channel recorders switch each channel alternately into the circuit, so that each component, recognized by the colour of the dot, is recorded at 2 min. intervals. At each hour U.T. the recorder is short-circuited for 2 min., so that two dots are made for zero input to the recorder. The second dot is taken to represent zero radiation, and the line of such dots forms the working base line.

2. *Calibration of the recorders*

The scale value of each recorder is determined monthly by passing a current through it for a few minutes and measuring the deflection of the dots from the base line determined by short-circuiting the recorder. The current was measured by a micro-ammeter in the early days, later by passing the current through a standard resistor and measuring the voltage across it by a potentiometer.

a. *Argentine Islands.* Calibrations were made for three deflections, about 15, 25 and 35 divisions, and these indicated that the response of the global and diffuse recorder was not linear. In 1974, measurements were made at eight points over the whole range and, using these and the long-term measurements for the three deflections, we derived the following best-fitting cubic equation relating the current i in micro-amps to the deflection y in chart divisions:

$$i = 1 \cdot 38y + 4 \cdot 87 \times 10^{-3} y^2 - 6 \cdot 02 \times 10^{-5} y^3.$$

The scale values measured for the 25 divisions range show small month-to-month variations, of less than 0·5 per cent of the mean annual values. However, there have been smooth secular changes in the annual mean values of this scale value, amounting to 1 per cent of the long-term mean value. We have found no cause of the secular change which is also seen in the recorder used for the reflected radiation and net radiation. We have adopted the mean value, as expressed in the equation above, for the whole period.

The recorder used for net radiation and reflected radiation shows little variation of sensitivity with deflection.

b. *Halley Bay.* At Halley Bay there is no bedrock on which to mount the recorders; the station is on an ice shelf which is in motion. The month-to-month calibrations show much greater variations than at the Argentine Islands; we attribute this to uncorrected tilting of the recorder.

An experiment was carried out in 1974 to measure the effect of tilting on the scale value of the recorder. Changes of level were measured by an Abney level. It was found that when the recorder was tilted sideways there was freedom of motion within a range of only 1° of tilt; jamming took place at both ends of this range. Through this range the scale factor increased from 1·18 μA div.$^{-1}$ at one end to 1·27 μA div.$^{-1}$ at the other for a deflection of about 15 divisions, and from 1·19 μA div.$^{-1}$ to 1·31 μA div.$^{-1}$ for 27 divisions. Tilting forwards or backwards had no appreciable effect on the scale value.

In another experiment, frequent calibrations were made while the temperature of the recorder was increased steadily by 10° C over a period of 6 hr. The scale value increased at a rate of 0·1 per cent °C^{-1}.

Routine monthly calibrations have been carried out for only one deflection, normally 40 divisions, but measurements made over the whole range on the global and diffuse recorder in 1974 established the relation

$$i = 1 \cdot 176y + 1 \cdot 3 \times 10^{-3} y^2.$$

Mean annual scale values normally differed by less than 1 per cent from values given by this relation but, for periods of several months mean scale values differed by as much as 3 per cent with individual values differing by as much as 10 per cent.

It is difficult to explain the variations in the calibration of the recorders and we can only suppose that, as the rapid variation of scale value was not then known, insufficient attention had been paid to the levelling of the recorders. We have adopted the relation given above.

For the reflected radiation recorder the following relation has been used:

$$i = 1 \cdot 04y + 1 \cdot 66 \times 10^{-3} y^2.$$

For the net radiation recorder a single scale value of $1 \cdot 47\ \mu$A div.$^{-1}$ has been used.

V. THE REDUCTION PROCEDURE USED TO OBTAIN MEAN HOURLY RADIATION VALUES

1. *Procedures at the stations*

A radiation diary is kept at each station. In these are noted, as soon after the event as possible, details of any instrument adjustments or calibrations, times when hoar frost or snow has been cleared from the instruments, duration and type of precipitation, etc.

The charts are changed daily, around local apparent midnight. The next morning they are examined and annotated with the more important details from the radiation diary. The base-line dots (p. 17) are identified and a line drawn through them. Local apparent noon is marked on the base line and lines normal to the base line are drawn at each exact hour of local apparent time.

If hoar frost or snow has affected the traces, and the appropriate interpolation is obvious, this is done at this time. Plate II shows a chart amended in this way. Hoar frost was deposited on the domes from 00.00 L.A.T. to 08.00 L.A.T. but was cleared (p. 19) sufficiently often for the run of the trace through the period to be well defined. The inverted solarimeter, measuring reflected radiation, was not affected.

Ordinates required to interpret calibrations are extracted. Further analysis is deferred until the charts and diaries have been received in the United Kingdom. There the charts are analysed by one of the physicists who had been responsible for the measurements.

2. *Extraction of ordinates*

Up to the end of 1964, mean hourly ordinates were estimated by eye. Since then, the charts have been reduced using digitizing tables. Data files are constructed containing identifiers (station, data and radiation component), base-line and hour-mark coordinates, and a number of trace coordinates (depending on the smoothness of the trace) such that linear interpolation will give an adequate representation of the record. These files were originally produced on paper tape but from 1969 onwards the digitizers have been interfaced to a small in-house computer (currently a PDP 11/40), which has been programmed to provide some interactive data validation.

This has proved to be very effective. With the paper-tape system, the programme written for processing the data contained elaborate traps for probable machine or operator errors. These traps were moderately successful but often the only recovery from a trap was to edit the paper tape and to re-run it. With the digitizers on-line, the format and coding of the data is assured, and the error traps have been discarded from the processing programme, giving a substantial saving in execution time.

The processing programme has been run on large computers (formerly at Edinburgh Regional Computing Centre, currently on the IBM 370/165 of the University of Cambridge Computing Centre, the PDP 11/40 being used as a remote job entry station) and it constructs files of mean hourly ordinates for each station year. A table of these mean ordinates, converted to chart divisions for ease of subsequent checking, is printed out.

3. *Conversion of ordinates to radiation values*

A radiation component, e.g. G, is related to the mean hourly ordinates, y, by the equation

$$GS\, f(t) = \Omega i(y),$$

where S is the sensitivity of the radiometer at 10° C, f(t) is the temperature factor given on p. 6 (p. 13 for R.B.M.), Ω is the circuit resistance, and $i(y)$ is the current passing through the recorder to give deflection y (see p. 17). The circuit resistance, Ω, is measured monthly and at times of seasonal changing of the series resistors. The assignment of values to S has been discussed on p. 8. The diffuse radiation is deduced from a similar equation, modified by the shade-ring correction (p. 15), i.e.

$$(1-r)DS\, f(t) = \Omega i(y).$$

Most changes in S and Ω are the results of deliberate adjustments, such as the replacement of one radiometer by another. There are, however, three cases where changes in factors in the conversion equation are quasi-continuous:

i. Change in S for an R.B.M. due to ageing (p. 13).
ii. The shade-ring factor (p. 15).
iii. The temperature factor.

We have chosen to represent the first two factors as piece-wise constant functions, introducing discontinuities of 1 per cent on appropriate dates, such that deviations from the true values do not exceed 0·5 per cent. We use the screen temperatures, observed every 3 hr., to evaluate the temperature factor for the 3 hr. (in local apparent time) nearest to the observation. These temperatures and other meteorological data are available from computer files constructed previously.

A control-data file containing the values of S, Ω and the shade-ring factor, and the dates on which changes occurred, is set up. The conversion programme is then run, using this control file, the mean ordinate file and the meteorological data file to produce files of mean hourly radiation values for each station year. We print out tables of the mean hourly values in W m.$^{-2}$ of the observed radiation components G, D and R, the global, diffuse and reflected short-wave (solar) radiation, and Q, the net radiation. Monthly sums for each hour L.A.T., daily and monthly sums are also listed.

Some consistency checks are then applied. We have found that these are more conveniently performed in terms of derived parameters rather than the observed components. Use is also made of the sunshine records (referred to on p. 3). We print out tables of SS, the duration of bright sunshine for each hour, in tenths of an hour; $G-D$, the horizontal projection of direct solar radiation; $A = R/G$, the local albedo; and $L = G-R-Q$, the long-wave radiation balance, measured as positive when upwards. A check list of anomalous values is also produced. This and the tables are then examined, making use of the radiation diaries. The identification and correction of some of the more common errors are discussed in the next section.

4. *Correction of radiation values*

a. *Effects of hydrometeors on short-wave radiation records.* A frequent cause of error in the records of short-wave radiation is the accumulation of hydrometeors (aggregates of liquid or solid water particles) on the domes of the solarimeters. All occurrences of hydrometeors should have been noted in the radiation diary and usually the instruments will have been inspected frequently and the domes cleaned, using warmth from the hand and a dry clean cloth. Nevertheless, short periods of, for example, hoar-frost deposition may go unnoticed in the field. The inverted solarimeter, measuring the reflected radiation, R, is rarely affected, and when this does happen the conditions (rime forming from fog) are such that they cannot escape notice. Hence, anomalous values of A, the albedo, may indicate that the domes of the upward-facing solarimeters have been covered by hydrometeors.

The anomalous values of A may be either high or low. Low values are, in our experience, due to a light deposit of hoar frost on the domes. This occurs mainly in calm conditions with low temperatures and clear skies, and is particularly troublesome in the early spring, late August and September. The hours immediately after sunrise are the most affected but hoar-frost formation can persist throughout the day. It occurs more often at Halley Bay than at the Argentine Islands. The low value of A is due to an apparent increase in the global radiation, G, which can amount to 100 per cent or more. The frosted dome is illuminated by the direct solar beam and the thermopile sees a bright artificial sky. Plate Ib, taken at the Argentine Islands, shows the global solarimeter with a heavy coating of hoar frost. The shadow cast by the frosted dome gives an indication of the way in which the direct solar radiation is "trapped" in such conditions. The diffuse solarimeter also gives an increased output, even though the dome is shaded from direct sunlight. This increase can also be quite large; 50 per cent or more has been observed. We find it difficult to account for an effect of this magnitude in terms of a re-distribution of sky brightness.

Additional illumination of the frosted dome may arise in two ways: by reflection of direct sunlight from the frosted guard plate and by brightening of the circum-solar sky. A prominent solar aureole is often seen when the layer of air depositing hoar frost is relatively thick.

Anomalously high values of A indicate an apparent deficit of G caused by obscuration of the dome. This may be due to an accumulation of snow, rime or ice (from freezing rain) and will usually be associated with an overcast sky. A thick deposit of hoar frost can cause an apparent decrease in G but, in practice, the dome will usually have been cleaned before the accumulation has grown to this extent.

Generally, we accept the recorded value of R and amend G to give a value of A consistent with the value derived from instantaneous values of R and G taken immediately after cleaning the domes, or with the values of A from neighbouring clear hours. For an overcast sky, D is set equal to the amended value of G. For a clear sky, D varies only slowly with solar zenith angle and can be estimated with fair accuracy from the general run of the trace. An example of the effects of hoar frost on the solarimeters is shown in Plate II. It can be seen that the reflected radiation record was not affected, whereas the global and diffuse radiation records show large apparent increases as the frost accumulated. We make no attempt to allow for the possible effect of the solar aureole described above. (There is no adequate practical definition of D^* in such conditions, cf. p. 16.)

b. *Effects of hydrometeors on net radiation records.* When the top surface of the sensitive plate of a balance meter gets wet, the forced ventilation produces strong cooling by evaporation and the record shows anomalously large negative values. A layer of snow on the plate can produce a similar but weaker effect. When the moisture spreads to the bottom surface of the plate, the effect depends critically on the symmetry of the ventilation and the record is unreliable, though often not distinctly anomalous. The records at the Argentine Islands are often seriously affected, since rain can occur even in mid-winter, and most heavy precipitation is associated with warm fronts. At Halley Bay, precipitation is seldom wet.

The forced ventilation is quite effective in preventing the accumulation of hoar frost or of dry snow. The records appear to be little affected by these hydrometeors. In fog depositing heavy rime, the inlet to the ventilation fans can become choked and the ventilation rate falls drastically. Rime can then spread to the plates. The record shows short-period fluctuations but the general level is seldom affected much.

The long-wave balance, $L = G-R-Q$, which at night is simply $-Q$, is predominantly positive at both stations. Exceptionally, the temperature at the base of a thick low cloud may be higher than the temperature of the snow surface, and L is then negative but small. We take $L < -10$ W m.$^{-2}$ to be anomalous. If the radiation diary confirms our view, we amend Q to be $G-R-L'$, deriving a mean value of L' from a nearby reliable part of the trace, or in default of such a value, using a climatological mean for the appropriate hour and month.

c. *Overcast skies.* The tabulated values of $G-D$ should be close to zero when the sky is overcast and provide a useful check on the G and D scale values (cf. p. 16). On a few occasions, adjustments of about 1 per cent have been made to the scale value for D when $G-D$ values for overcast skies showed a persistent bias.

d. *Reflection of sun in sea.* At the Argentine Islands, at certain times in the evening, solar radiation which has been reflected by the sea reaches the reflected radiation solarimeter and the underside of the radiation balance meter. It could be argued that this is a natural phenomenon and no correction should be applied for it but we decided that, as it causes an albedo of well over 1·0 to be recorded, the effect of the specular reflection of the solar radiation should be removed. This is done by reducing R to give values of A consistent with nearby unperturbed values.

e. *Closure of Halley Bay in 1968.* No radiation records were taken at Halley Bay in the period 25–31 March 1968, when the station was being moved to a new site, and there were only restricted records for the previous week. The sky was mainly overcast, with stratocumulus cloud, typical of the season. From the amount and type of cloud, and the duration of sunshine in each hour, we have estimated the radiation components for every hour, based on radiation measured in other years under similar conditions.

5. *Final tables of hourly radiation values*

The computer files have been edited to incorporate the amendments determined as described above. Checks have been imposed to trap amendments which would themselves be anomalous, whether due to faulty determination or to errors in transcription. The files have then been re-examined to ensure that all anomalies previously identified have been amended or substantiated.

The identification of chart base lines is subject to an error of about 2 W m.$^{-2}$, which may be systematic for a component throughout a day. Scale errors are about 1 per cent at solar elevations exceeding 25°, increasing to perhaps 5 per cent for global radiation under a clear sky with solar elevation less than 15°. For completeness, we have tabulated values of short-wave radiation (G, D and R) as low as 1 W m.$^{-2}$ at the beginning and at the end of a day. This is compatible with the overall resolution of the recording and reduction procedures, but the noise level in the smaller values is high, and the consistency of the radiation components can be poor. We have decided that, for those hours when $G \leqslant 20$ W m.$^{-2}$, the consistency can be enhanced, with little loss of real information, by the following procedure:

i. If D and R both exceed G, we set $G = \max. (D, R)$.
ii. We amend R or G (the logical inclusive "or") by ± 1 W m.$^{-2}$ to give the best agreement with the mean albedo for neighbouring hours.
iii. We amend D, if necessary, so that $G-D$, which is the vertical component ($I \cos z$) of the direct solar radiation does not exceed the value possible in a Rayleigh atmosphere, using a restricted solar spectrum, $\lambda \leqslant$ 1,200 nm., since the longer wave-lengths are severely attenuated at very low solar elevations. (We were prompted to include this constraint by a case known to us, where I near sunrise was "estimated" as $(G-D) \sec z$!) The tabulated values for such hours are therefore "best estimates" rather than measured values.

A further problem of consistency arises in the main body of the tables. As noted earlier, the values of $G-D$ obtained for overcast skies are randomly distributed about zero, while physically of course D cannot exceed G. The standard deviation of $G-D$ in such conditions is about 2 W m.$^{-2}$ (less than 1 per cent when the solar elevation exceeds 15°). For simplicity, we have merely reduced D to G whenever D exceeded G.

This completes the reduction procedure, and the final tables are printed out. These are too extensive to be reproduced in this paper and a copy has been sent to the World Data Centre in Moscow. Summaries of the data are given on p. 32–49, and are described briefly below.

6. *Summaries of the hourly values*

Monthly sums are presented in Appendix A, for the Argentine Islands, and in Appendix B, for Halley Bay. In leap years, the recorded sums for February have been reduced by 28/29 for ease of comparison with other years. There were no records of reflected solar radiation at the Argentine Islands in January 1963. The sum for that month has been estimated.

The remaining tables have entries for each third of each month. Appendices C and D give the mean, the extremes and the standard deviation of the daily sums over the 10 years. Appendices E and F give the mean radiation values for each hour of local apparent time. Two ancillary tables, Appendices G and H, show values of cos z (where z is the solar zenith angle) at the half-hours of local apparent time, in units of 0·01.

VI. DIRECT SOLAR RADIATION AND CLEAR-SKY RADIATION

1. *Selection of cloudless periods*

We have examined the radiation and meteorological records and have selected occasions when the sky was deemed to be clear of cloud, apart from traces of cloud near the horizon, e.g. small amounts of distant cloud over open water or orographic cloud over distant mountains as frequently observed at the Argentine Islands. Such clear conditions do not occur frequently at either of the stations, although there is a tendency for cloudless periods of a few days to occur at Halley Bay, particularly around midsummer.

Values of I have been derived from pyrheliometer observations, using the constants given in Table I and corrected to the value I_0 for mean solar distance by multiplying by the factor $a = R^2/R_m^2$, where R_m and R are the mean and actual solar distances. Other values of I_0, and these are always local noon values, have been derived from determination of G_0 and D_0 from the radiation record, and use of the equation $I_0 = (G_0 - D_0) \sec z$. G_0 is calculated from the equation

$$G_0 = a y_G \, k(y_G) \, \Omega_G / S_G \, f(t),$$

where y_G is the ordinate of the global radiation trace, $k(y_G)$ is the scale value of the recorder for a deflection Y_G, Ω_G the resistance of the global solarimeter circuit, S_G the sensitivity of the global solarimeter at standard temperature of 10° C, and $f(t)$ is the ratio of the sensitivity of a solarimeter at temperature t to its sensitivity at 10° C.

D_0 is calculated from the equation

$$D_0 = 1 \cdot 03 \, a y_D \, k(y_D) \, \Omega_D / S_D \, f(t) \, (1-r),$$

where $1/(1-r)$ is the geometric shade-ring correction and the other symbols have the same meaning as in the case of G_0. The factor 1·03 is introduced as an approximate correction to the geometric shade-ring correction for clear skies in accordance with the conclusion on p. 15.

Over the period spring 1962–autumn 1973, a number of reliable simultaneous values of I_0 and D_0 have been obtained from both stations after rejection of observations which appear to have been affected by cloud, and some which were clearly in error. A selection of several values for each summer season are given in Table XIII; they have been selected as being representative of the general level of I_0 and D_0 for the given value of air mass m at the time.

2. *Attenuation of direct solar radiation*

We have used for our model the solar spectrum advocated by Kondratyev (1972) with a solar constant of 1,353 W m.$^{-2}$, and have separately and independently derived the attenuation due to:

i. Rayleigh scattering; we have used the scattering coefficients given in table 3.2 of Robinson (1966).
ii. Absorption by water vapour; we have used the absorption coefficients given by McClatchey and others (1972) and the total precipitable water content of the atmosphere as derived from the noon radio-sonde ascent.
iii. Absorption by ozone; we have used the absorption coefficients given by Vigroux (1953) and the amount of ozone measured at the station on that day by the Dobson spectrophotometer.
iv. Absorption by the uniformly mixed gases (including the 760 nm. molecular oxygen band); we have used the absorption coefficients given by McClatchey and others (1972).

There is some overlapping of the attenuation bands, particularly for Rayleigh scattering and ozone absorption, and for water vapour and the uniformly mixed gases, and corrections must be made for this. If a_1, a_2 are the attenuation coefficients of two agents in a certain spectral range, the fraction of energy transmitted is $(1-a_1)(1-a_2)$ and the attenuation is $a_1+a_2-a_1a_2$. Thus the attenuation computed by considering the two agents separately overestimates the attenuation by the amount a_1a_2. The quantity a_1a_2 is slow moving and easy to estimate—the correction for the overlapping of water vapour and the uniformly mixed gases amounts to 9 W m.$^{-2}$ for all normal amounts of precipitable water over the range $m = 1 \cdot 4$—$2 \cdot 2$.

The values used in the model calculation of loss of energy by attenuation by the various agents for values of $m = 1 \cdot 3$ (midsummer noon at the Argentine Islands), 1·7 (midsummer noon at Halley Bay) and 2·1 are given in Table XIV.

The sum of all the attenuations, corrected for overlapping, and I_0 fall short of the solar constant, 1,353 W m.$^{-2}$, and the difference ΔI_0 is attributed to aerosol attenuation. To normalize the measurements made over a range of m, the quantity $\Delta I_0/m$, i.e. the aerosol attenuation per unit air mass, is calculated and given in Table XIII.

Table XIII

AEROSOL ATTENUATION, TURBIDITY AND CLEAR-SKY RADIATION (UNITS W m.$^{-2}$)

Argentine Islands

Date		m	I_0	$\frac{\Delta I_0}{m}$	β	D_0	$D_0(1\cdot7)$
1962–63							
27 Nov.	S	1·38	978	31		107	97
29 Dec.	S	1·30	985	40		95	84
26 Jan.	S	1·43	980	25		81	74
1963–64							
7 Oct.	P	2·03	930	26		98	106
22 Oct.	S	1·66	940	36	0·027	112	111
1 Nov.	P	1·67	958	37	0·031	114	113
11 Nov.	P	1·49	969	48	0·027	122	114
29 Nov.	P	1·89	824	77	0·036	141	148
13 Dec.	P	1·95	723	118	0·058	174	186
18 Dec.	P	1·34	843	143	0·071	228	202
10 Jan.	P	1·48	775	157	0·063	224	209
28 Jan.	P	1·71	725	158	0·079		
12 Feb.	P	1·59	743	158	0·072	224	216
22 Feb.	P	1·72	732	157	0·073	213	215
1 Mar.	P	1·86	686	152	0·078	207	215
1964–65							
4 Nov.	P	1·71	767	126		207	205
9 Nov.	P	1·50	759	173	0·074	253	238
9 Dec.	P	1·67	792	120	0·071	184	182
18 Dec.	P	1·92	818	78		139	148
5 Jan.	P	1·64	833	94	0·050	175	172
22 Jan.	P	1·56	838	111	0·057	164	157
20 Feb.	P	1·73	833	91	0·028	150	152
1965–66							
8 Oct.	P	1·94	914	45	0·024	114	122
28 Oct.	P	1·59	933	56	0·034	126	122
29 Nov.	P	1·65	929	42	0·032	119	117
13 Dec.	P	1·85	884	51	0·035	104	108
8 Jan.	P	2·06	863	47	0·031	95	104
27 Jan.	P	1·89	892	46	0·035	90	95
4 Feb.	P	1·87	909	34	0·025	80	84
24 Feb.	P	1·77	921	36		88	90
1966–67							
6 Nov.	P	1·58	968	33	0·015	117	113
14 Dec.	P	1·61	957	30	0·014	112	109
7 Jan.	P	1·38	977	41	0·021	111	99
17 Feb.	P	1·76	937	34	0·019	87	89
1967–68							
26 Oct.	P	1·81	931	37		116	120
15 Nov.	P	1·46	1,005	30	0·017	106	98
7 Dec.	P	1·44	982	29		95	88
1 Dec.	S	1·48	973	27		81	76
1968–69							
22 Nov.	S	1·39	990	20		107	97
22 Dec.	S	1·33	992	34		110	97
6 Feb.	S	1·53	964	34		90	85
19 Feb.	S	1·67	957	26		69	68
1969–70							
7 Oct.	P	1·93	926	35		94	100
21 Dec.	S	1·33	1,009	32		88	98
13 Jan.	P	1·38	976	38		103	93
1970–71							
7 Oct.	P	1·99	919	34		94	102
22 Dec.	P	1·32	994	35		92	81
22 Jan.	S	1·41	997	25		78	71
12 Feb.	S	1·58	970	29		68	66
1971–72							
4 Nov.	S	1·52	992	18		99	93
1 Dec.	S	1·38	975	37		95	86
28 Dec.	S	1·35	993	32		79	70
12 Feb.	S	1·59	960	23		60	58
1972–73							
23 Oct.	S	1·67	980	13		69	68
31 Dec.	S	1·34	1,006	17		67	59
20 Jan.	S	1·39	987	27		69	62
17 Feb.	S	1·67	965	20		66	65

Halley Bay

Date		m	I_0	$\frac{\Delta I_0}{m}$	D_0	$D_0(1\cdot7)$
1962–63						
14 Nov.	S	1·84	963	21	91	95
16 Dec.	S	1·61	979	25	93	90
26 Jan.	S	1·78	967	28	88	90
1963–64						
11 Nov.	P	1·86	961	26	98	102
22 Nov.	P	1·73	937	49	123	124
25 Nov.	P	1·69	895	68	145	144
6 Dec.	P	1·85	790	113	165	172
13 Dec.	S	1·63	766	149	215	210
21 Dec.	P	1·62	812	119	197	192
25 Dec.	S	1·61	813	127	194	188
31 Dec.	S	1·64	797	128	197	193
2 Jan.	S	1·64	804	120	194	190
11 Jan.	S	1·70	742	154	209	209
26 Jan.	S	1·81	742	136	206	212
12 Feb.	S	2·11	705	125	160	178
18 Feb.	S	2·20	694	117	156	177
1964–65						
9 Nov.	S	1·92	828	94	161	171
18 Nov.	P	1·79	864	70	155	160
3 Dec.	P	1·70	847	99	189	189
9 Dec.	S	1·64	822	120	189	185
27 Jan.	S	1·84	853	75	140	146
11 Feb.	S	2·10	797	84	132	147
1965–66						
16 Nov.	S	1·79	869	72		
16 Dec.	S	1·63	918	60	125	123
27 Dec.	P	1·61	949	40	114	111
16 Feb.	P	2·22	910	25	79	90
1966–67						
11 Nov.	S	1·89	962	26	91	96
20 Nov.	S	1·76	957	26	93	95
29 Dec.	S	1·61	961	26	97	94
5 Jan.	S	1·65	959	27	96	95
23 Jan.	S	1·79	939	23	92	94
1967–68						
4 Nov.	P	2·03	937	30	85	93
20 Nov.	S	1·75	964	29	98	99
7 Dec.	P	1·66	951	34	99	98
5 Jan.	S	1·64	959	33	104	102
7 Feb.	P	1·99	908	35	91	98
1968–69						
1 Nov.	P	2·03	921	32	98	107
25 Nov.	P	1·72	965	23	95	96
14 Dec.	S	1·61	993	20	99	96
4 Jan.	S	1·64	970	21	93	91
7 Feb.	S	2·00	944	18	82	87
1969–70						
29 Oct.	S	2·09	930	26	84	93
19 Nov.	S	1·78	971	22	89	91
12 Dec.	S	1·61	998	14	90	87
26 Jan.	S	1·80	945	23	81	84
1970–71						
12 Nov.	S	1·87	976	11	79	83
29 Nov.	S	1·69	995	14	86	86
21 Dec.	S	1·61	989	12	89	86
19 Jan.	S	1·71	971	12	85	85
5 Feb.	S	1·97	939	23	74	80
1971–72						
30 Oct.	S	2·04	956	16	72	79
16 Nov.	P	1·82	982	15	76	79
3 Dec.	P	1·66	973	20	75	74
25 Dec.	S	1·63	964	18	80	78
19 Jan.	P	1·75	972	13	72	73
8 Feb.	P	2·02	921	21	57	62
1972–73						
27 Oct.	S	2·14	928	25	69	77
21 Nov.	S	1·73	988	9	69	70
12 Dec.	P	1·92	937	19	62	66
22 Dec.	P	1·61	969	18	77	75
1 Jan.	S	1·63	979	13	66	65
5 Feb.	S	2·01	952	10	71	77

S Solarimeter.
P Pyrheliometer.

TABLE XIV
VALUES USED IN THE MODEL CALCULATIONS OF ATTENUATION OF DIRECT SOLAR RADIATION (UNITS W m.$^{-2}$)

	No filter			*Filter*	
				RG2	OG1
m	1·3	1·7	2·1	1·7	1·7
Rayleigh scattering	160	195	225	174	150
Ozone absorption					
$x = 250$ m atm–cm.	36	40	44	37	29
$x = 350$ m atm–cm.	41	47	53	43	32
$x = 450$ m atm–cm.	47	54	60	49	34
Rayleigh/ozone overlapping					
$x = 250$ m atm–cm.	−23	−27	−31	−26	−25
$x = 350$ m atm–cm.	−25	−29	−33	−28	−27
$x = 450$ m atm–cm.	−27	−31	−35	−30	−29
Water-vapour absorption					
$w = 0·4$ cm.	107	115	123	13	13
$w = 0·7$ cm.	126	135	141	15	15
$w = 1·0$ cm.	137	146	152	16	16
Uniformly mixed gases	14	15	17	5	5
Aerosol scattering					
$\beta = 0·01$	28	37	45	23	17
$\beta = 0·03$	83	107	131	67	49
$\beta = 0·05$	134	173	208	106	78
Aerosol/Rayleigh/ozone overlapping					
$\beta = 0·01$	−6	−9	−12	−9	−8
$\beta = 0·03$	−18	−27	−36	−26	−23
$\beta = 0·05$	−26	−41	−55	−38	−35

The quantity ΔI_0 is very sensitive to errors of measurement and in the solar constant; an error of 1 per cent in the radiation measurement would result in an error of about 6 W m.$^{-2}$ in $\Delta I_0/m$. An error of 1 per cent in the solar constant would lead to an error of about 8 W m.$^{-2}$ in $\Delta I_0/m$.

3. *Sky radiation*

In an aerosol-free atmosphere, the energy scattered by the air molecules after absorption by ozone is

$$E_R = \int E_\lambda R_\lambda (1-\alpha_\lambda) d\lambda,$$

where R_λ is the Rayleigh scattering coefficient, α_λ the ozone absorption coefficient at wave-length λ, and E_λ is the energy in the wave band of width $d\lambda$.

Deirmendjian and Sekera (1954) have given absolute values for the global and diffuse radiation resulting from multiple scattering in a Rayleigh atmosphere. These values, for a plane-parallel model atmosphere, are exact in the sense that they include the effects of all orders of scattering and the effect of ground reflection. Rather simple expirical expressions can be fitted to their results (integrated over the solar spectrum) with reasonable accuracy:

i. $D(0)$, the diffuse radiation received when the ground is non-reflective, is given by

$$D(0) = f_R E_R \cos z,$$

where f_R is the fraction of the scattered radiation scattered forward. For $0·6 \leqslant \cos z \leqslant 1, f_R = 0·48$ to a fair approximation, while $f_R = (0·429+0·0005\ E_R)$ provides an accuracy of 1 W m.$^{-2}$ for all zenith angles. Rayleigh scattering is symmetrical and $f_R = 0·5$ would be appropriate if primary scattering alone were effective.

ii. $D(A)$, the diffuse radiation received when the ground is a Lambert reflector of albedo A, is greater than $D(0)$ due to multiple reflection between the sky and the ground of both the direct radiation and of the diffuse radiation $D(0)$ itself. To calculate this effect, it is sufficient to treat the sky as a Lambert reflector with albedo B. Then

$$D(A) = (D(0)+ABI\cos z)/(1-AB) \quad (1)$$
$$\text{or } D(A)-D(0) = AB\,(D(0)+I\cos z) = ABG,$$

where G is the global radiation received when the ground albedo is A. To a fair approximation, $B = 0{\cdot}065$ for all values of A when $0 \leqslant \cos z \leqslant 0{\cdot}8$.

As the measurements of D_0 in Table XIII have been made over a range of m from 1·3 to 2·1 approximately, it is convenient to normalize them to a standard value of m; a value of 1·7 has been chosen for this. To determine the normalizing factor $D_0(1{\cdot}7)/D_0$, we have selected periods of clear sky within 10 days of midsummer and have tabulated the mean hourly values of D_0 for each hour of the day. For each station about 12 periods were obtained and median values for each hour were derived and plotted against m. From each curve, values of the normalizing factor $D_0(1{\cdot}7)/D_0$ were derived and plotted as a function of m; the curves for the two stations were similar and the values of the normalizing factor for clear midsummer days are given in Table XV together with the theoretical values.

TABLE XV

VALUES OF THE MODEL SKY RADIATION IN AN AEROSOL-FREE ATMOSPHERE AND THE NORMALIZING FACTORS (UNITS W m.$^{-2}$)

	m 1·3	1·7	2·1
D_0			
Albedo = 0·8	104	86	72
Albedo = 0·25	65	59	53
Albedo = 0	50	47	44
Normalizing factor $D_0(1{\cdot}7)/D_0$			
Albedo = 0·8	0·83	1	1·19
Albedo = 0·25	0·91	1	1·11
Albedo = 0	0·94	1	1·07
Clear midsummer days	0·88	1	1·11

The effect of the albedo on the model sky radiation is illustrated by the values of D_0 in Table XV; for $m = 1{\cdot}7$ a change of albedo from 0·8 to 0·25, as may occur in the course of the summer at the Argentine Islands, results in a decrease of 27 W m.$^{-2}$ in the model sky radiation.

In dust-free seasons (see p. 25) at the Argentine Islands $D_0(1{\cdot}7)$ exceeds the model value for albedo 0·8 early in the season and falls below it at the end, whereas at Halley Bay $D_0(1{\cdot}7)$ normally exceeds the high albedo model value throughout the season. However, in recent years, which have been notable for the amount of open water in this sector of the Antarctic, lower values of $D_0(1{\cdot}7)$ occurred throughout the season, with exceptionally low values, similar at the two stations, in 1972–73, when the attenuation was also somewhat lower than normal.

4. *The effect of volcanic dust*

A striking feature of the values of $\Delta I_0/m$ and $D_0(1{\cdot}7)$ in Table XIII is the steep increase, which began in November 1963 and continued during December to reach maximum values in January and February 1964. This is attributed to the influx of volcanic dust from the eruption of Mount Agung (lat. 8° S., long. 115° E.) on 17 March 1963. The changes in normalized diffuse radiation, $D_0(1{\cdot}7)$, are illustrated in Fig. 2. Values of $D_0(1{\cdot}7)$ for a Rayleigh atmosphere over surfaces of albedo 0, 0·25 and 0·80 are shown at the right-hand edge of the figure.

In the pre-eruption summer of 1962–63, $D_0(1{\cdot}7)$ remained around 93 W m.$^{-2}$ throughout the summer at Halley Bay, while at the Argentine Islands there was a decrease from around 95 W m.$^{-2}$ to around 75 W m.$^{-2}$, probably due to a decrease in the albedo.

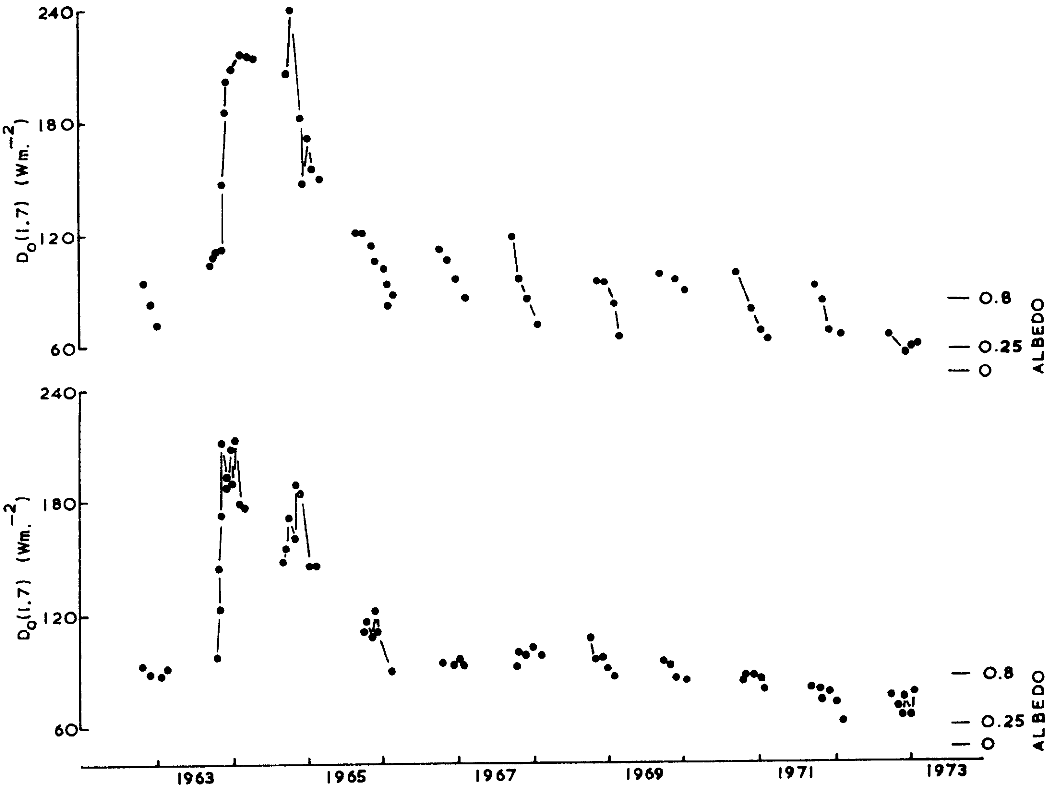

FIGURE 2

Normalized diffuse radiation at the Argentine Islands and Halley Bay, 1963–72.

In 1963–64, values were steady and slightly higher than in the previous season up to 11 November, and then increased rapidly. The course of the increase cannot be followed in detail as cloud permitted only one measurement of $D_0(1\cdot7)$ at the Argentine Islands, and two at Halley Bay in the next month. At both stations values of around 200 W m.$^{-2}$ were reached by mid-December.

In 1964–65, $D_0(1\cdot7)$ rose rapidly at Halley Bay until early December, and then decreased, but at the Argentine Islands $D_0(1\cdot7)$ was very high when the first measurement was made on 4 November, reached a maximum value of 238 W m.$^{-2}$ (confirmed by a very high value of $\Delta I_0/m$) on 9 November and thereafter decreased steadily.

In 1965–66, the conditions were nearly back to normal with low values of $D_0(1\cdot7)$, decreasing slightly during the season.

The values of $D_0(1\cdot7)$ in the last months of 1963, 1964 and 1965 are given in Table XVI together with the temperature at 100 mbar and the amount of ozone measured on the same day. In 1963, the increase in $D_0(1\cdot7)$ was accompanied at both stations by an increase of 100 mbar temperature of 20° C and of ozone amount of 100 m atm–cm. This is the spring warming associated with the break-down of the winter polar vortex. In 1964, the spring warming had already taken place at the Argentine Islands when the first sky radiation measurements were possible, and the values of $D_0(1\cdot7)$, T_{100} and x were all high. At Halley Bay, the values of $D_0(1\cdot7)$ and T_{100} increased from late October until early December when there was also a rather small increase in ozone amount. In 1965 there was no increase of sky radiation at the time of the spring warming.

5. *Relation of diffuse radiation to the extinction due to dust*

Fig. 2 shows that when the dust effects were most marked the diffuse radiation for a relative air mass, m, of $1\cdot7$ rose to over 200 W m.$^{-2}$ from values around 90 W m.$^{-2}$. The global radiation decreased only slightly, by perhaps 10 W m.$^{-2}$ from 660 W m.$^{-2}$. This change in global radiation could be caused by a small change in the precipitable water content of the atmosphere (from $0\cdot7$ cm. to $1\cdot0$ cm. at $m = 1\cdot7$), so

TABLE XVI

MEASUREMENTS OF SKY RADIATION (NORMALIZED TO $m = 1 \cdot 7$), 100 mbar TEMPERATURE AND OZONE AMOUNT

Argentine Islands				Halley Bay			
Date	$D_0(1 \cdot 7)$ (W m.$^{-2}$)	T_{100} (°C)	x (m atm-cm.)	Date	$D_0(1 \cdot 7)$ (W m.$^{-2}$)	T_{100} (°C)	x (m atm-cm.)
1963				*1963*			
7 Oct.	106	−69	359	2 Nov.	107	−66	312
22 Oct.	111	−68	292	5 Nov.	106	−68	295
29 Oct.	119	−69	306	11 Nov.	102	−62	325
1 Nov.	113	−65	297	22 Nov.	124	−43	423
3 Nov.	115	−64	290	25 Nov.	144	−40	426
29 Nov.	148	−42	396	13 Dec.	210	−39	370
13 Dec.	186	−44	363	21 Dec.	192	−40	337
18 Dec.	202	−44	361	25 Dec.	188	−42	341
				31 Dec.	193	−43	321
1964				*1964*			
4 Nov.	205	−47	388	17 Oct.	149	−71	310
9 Nov.	238	−41	393	27 Oct.	155	−67	311
20 Nov.	172	−50	350	7 Nov.	171	−50	299
5 Dec.	187	−40	368	18 Nov.	160	−46	323
9 Dec.	182	−43	371	27 Nov.	186	−39	320
18 Dec.	148	−47	299	3 Dec.	189	−40	351
				9 Dec.	185	−42	343
1965				*1965*			
8 Oct.	122	−73	314	1 Nov.	111	−66	285
28 Oct.	122	−64	339	16 Nov.	117	−59	297
29 Nov.	117	−50	350	1 Dec.	108	−53	331
5 Dec.	107	−48	340	16 Dec.	123	−41	348
11 Dec.	104	−45	370	27 Dec.	111	−41	335
13 Dec.	108	−43	396				
21 Dec.	115	−44	344				

that it is clear that a more detailed analysis is required to obtain quantitative results. Nevertheless, it is evident that the scattering by the dust must be strongly forward directed. This conclusion will be exploited in the analysis below.

Fig. 3 shows the measured diffuse radiation plotted against $\Delta I \cos z$. Least-square lines have been fitted for each station. The slopes are almost identical and have a mean value of $0 \cdot 95$. Thus the loss in the direct radiation received by a horizontal surface due to extinction by the dust is almost completely compensated by the gain in diffuse radiation. Calculations using a simple model, given below, suggest that this result is independent of the albedo of the ground and that, if the dust is non-absorbing, the slope of the line gives directly the fraction of the extinction which is scattered forward.

It is generally agreed that the main concentration of the Mount Agung dust was to be found in the stratosphere. The account, given above, of its arrival at Halley Bay supports this view. Hence, the scattering by the dust occurs at levels above those at which most of the Rayleigh scattering takes place. Using the conclusion that the dust scatters strongly forward, it may be argued that the Rayleigh extinction, E_R, is little affected by the presence of dust. Further, the dust will not appreciably alter the sky albedo, B. The diffuse radiation, $D_D(A)$, received when dust is present, is then most simply found by considering only the extra extinction due to dust and this is the quantity ΔI as defined above.

$$D_D(A) = (D(0) + f_D \, \Delta I \cos z + AB(I - \Delta I) \cos z)/(1 - AB),$$

where f_D is the fraction of ΔI which is scattered forward. Then, using Equation (1),

$$D_D(A) - D(A) = (\Delta I \cos z)\,(f_D - AB)/(1 - AB).$$

When $(1 - f_D)$ and AB are less than $0 \cdot 1$, then to within 1 per cent

$$f_D = (D_D(A) - D(A))/\Delta I \cos z.$$

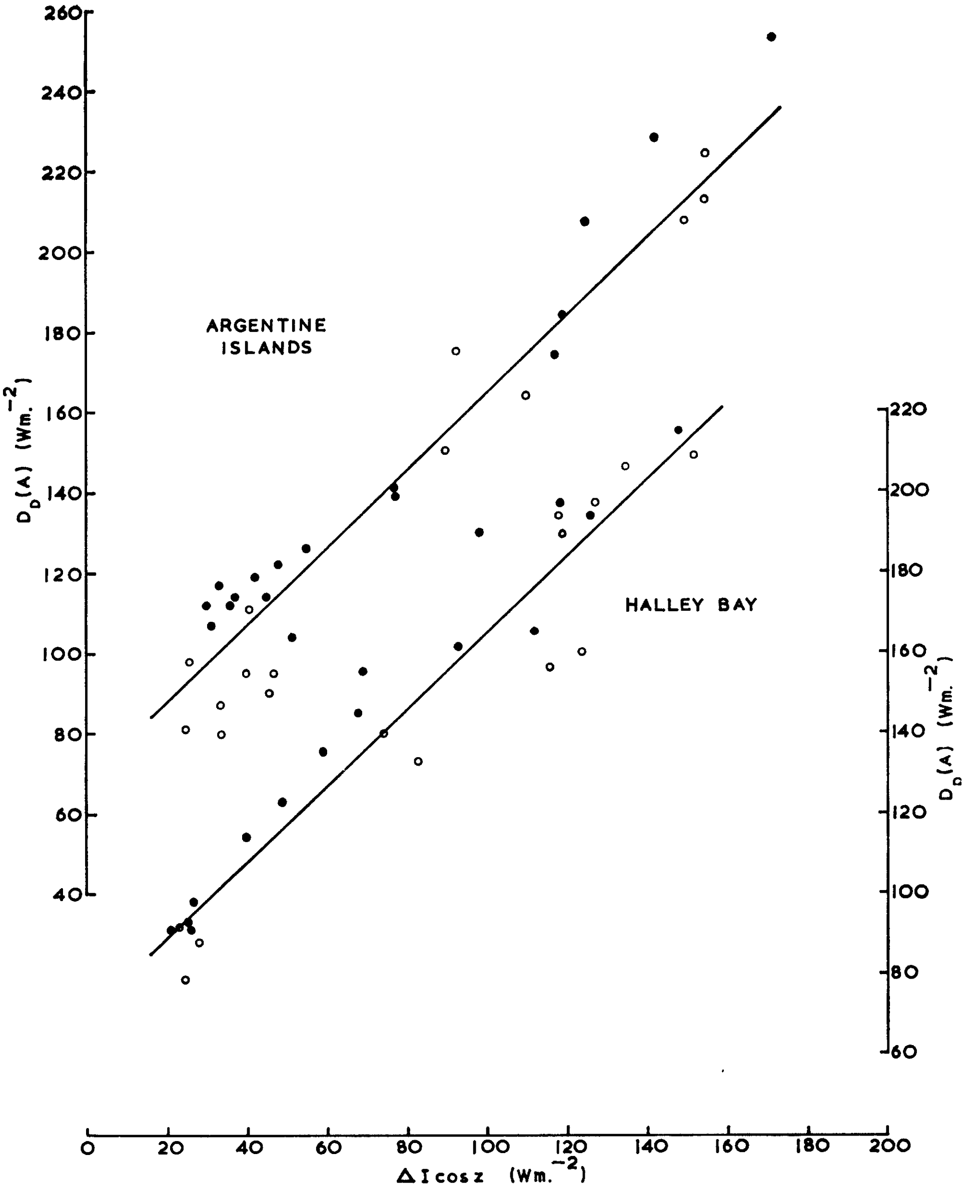

FIGURE 3

Variation of $D_D(A)$ with $\Delta I \cos z$ at the Argentine Islands and Halley Bay.

Now, $D(A)$ varies only slightly with cos z, for $0{\cdot}8 \geqslant \cos z \geqslant 0{\cdot}5$ and, although it varies considerably with A, changes in A and $\Delta I \cos z$ are unrelated. Hence, the slope $D_D(A)/\Delta I \cos z$, shown in Fig. 3, yields f_D directly and independently of A or B.

The value derived for f_D, 0·95, may be compared with the effects of scattering by spherical particles of diameter greater than 1 μm. Such scattering is adequately represented as Fraunhofer diffraction. The forward scattering is confined to a lobe of width $35/d$ degrees (for a wave-length of 500 nm.), where d is the particle diameter in μm., and this lobe contains 0·84 of the incident radiation. This fraction is not very sensitive to the shape of the particles. Smaller spherical particles (0·6–0·8 μm. have been suggested as typical diameters for the Mount Agung dust) would not be so effective but it is believed that particles of highly irregular shape with typical dimensions in this range might be highly effective forward scatterers.

It should be remarked that while errors of around 1 per cent in the assumed value of the solar constant, or in the model calculations, or in the calibration of the pyrheliometer or total solarimeter will have an appreciable effect in the absolute values of $\Delta I \cos z$, they will have only a small effect on the slope of the lines in Fig. 3.

6. *Variation of the scattering coefficient for volcanic dust with wave-length*

At the Argentine Islands, many measurements of direct solar radiation have been made using standard OG1 and RG2 filters on an Ångstrom pyrheliometer. These filters were calibrated at the Physikalisch-Meteorologische Observatorium, Davos. They transmit radiation in the bands 525–2,800 and 630–2,800 nm., respectively. The intensity, I_L, of the direct solar radiation at wave-lengths longer than 2,800 nm. is small and varies only from about 9 to 16 W m.$^{-2}$ depending on the amount of precipitable water, w, in the path. Values of I_L for various values of w sec z are given in the I.G.Y. instruction manual (C.S.A.G.I., 1958).

If I_{OG} and I_U are the intensities measured with and without the OG1 filter,

$$I_Y = \int_{\lambda<525\text{ nm.}} I_0(\lambda) \times d\lambda = a(I_U - I_{OG} - I_L),$$

where a is the factor to correct to mean solar distance (p. 22). I_R, the integrated intensity for λ <630 nm., can be found similarly. For these wave bands, in the absence of aerosol and volcanic dust, extinction is due to ozone absorption and Rayleigh scattering only. Extinctions have been calculated for these two spectral ranges, in the same way as in the case of observations without filters (p. 22), and the deficits ΔI_Y and ΔI_R determined.

These deficits are usually interpreted as being due to aerosol scattering, with extinction coefficient $m\beta\lambda^{-1\cdot3}$; β, the Ångstrom turbidity coefficient, is a measure of the aerosol concentration per unit air mass. The values of β given in Table XIII were deduced from the measured values of I_R using table 7 in the I.G.Y. instruction manual (C.S.A.G.I., 1958), which is based on the solar spectrum as specified by Nicolet (1951) with a solar constant of 1,380 W m.$^{-2}$. The general level of β, when the effects of the Mount Agung dust had passed, was about 0·02. In the presence of the dust, values of β up to 0·08 were obtained. Fig. 4 shows that the corresponding contrasts in $\Delta I_Y/m$ and $\Delta I_R/m$ were about 1:4, and for $\Delta I_0/m$ about 1:5. It may be deduced that the extinction due to the Mount Agung dust was relatively greater at the longer wave-lengths than in the case of normal aerosol, and that $\lambda^{-1\cdot3}$ is not the appropriate wave-length dependence of extinction for dust.

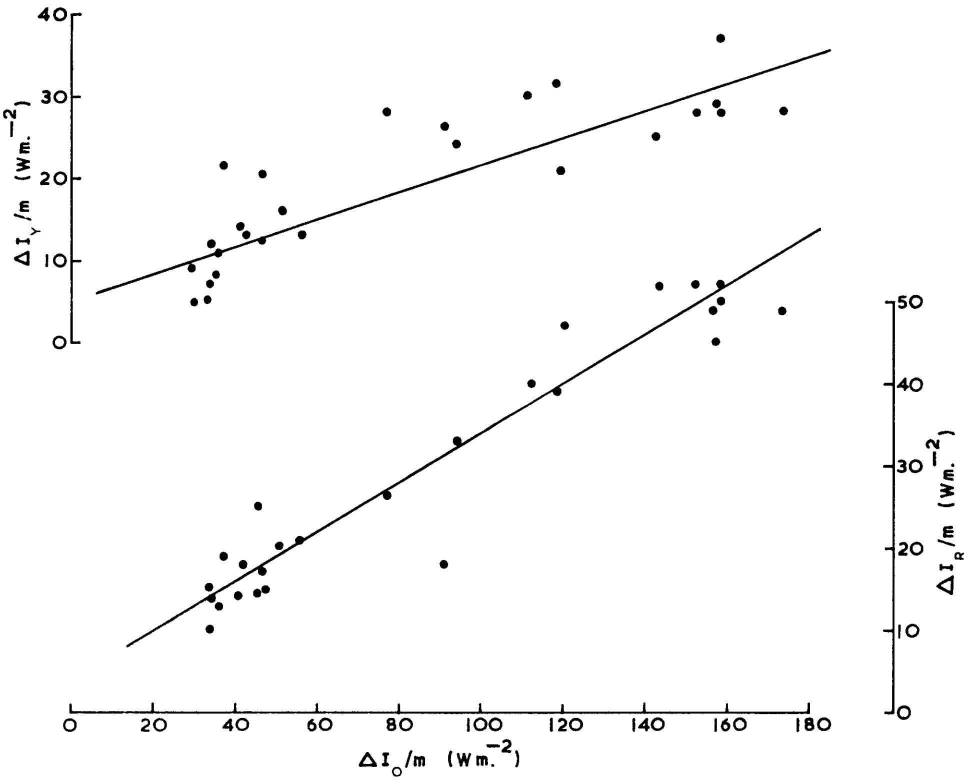

FIGURE 4

Variation of $\Delta I_Y/m$ and $\Delta I_R/m$ with $\Delta I_0/m$ at the Argentine Islands.

In principle, when both ΔI_Y and ΔI_R are available, it is possible to generalize the extinction coefficient to $m\beta\lambda^{-\alpha}$, and to determine β and α separately for each set of observations. In practice the exponent α is very sensitive to observational errors, particularly when the deficits are small. A better approach is to utilize the ratios of the extinction deficits, which can be derived from Fig. 4. The gradients of the best-fitting lines for $\Delta I_Y/\Delta I_0$ and $\Delta I_R/\Delta I_0$ are 0·19 and 0·30. These may be compared with model calculations as follows. The spectrum of the direct radiation received at the ground, for $m = 1\cdot7$, has been calculated, making due allowance for Rayleigh scattering, absorption by 350 m atm-cm. of ozone, absorption by 0·8 cm. of precipitable water and aerosol extinction with $\beta = 0\cdot02$ and $\alpha = 1\cdot3$. The additional extinctions by dust for various values of α have then been determined, and the ratios $\Delta I_Y/\Delta I_0$ and $\Delta I_R/\Delta I_0$ derived are:

α	2·0	1·3	0·7	0	–0·5
$\Delta I_Y/\Delta I_0$	0·45	0·37	0·29	0·19	0·13
$\Delta I_R/\Delta I_0$	0·65	0·56	0·47	0·33	0·24

It appears that for the Mount Agung dust, $\alpha = 0$ approximately, i.e. that the scattering is almost independent of wave-length.

7. *Discussion*

It has been shown that the global radiation, received at sea-level, was only slightly reduced when dust from the Mount Agung eruption was present over two Antarctic stations. Even when the effects of the dust were most marked, the loss was only 10 W m.$^{-2}$, about $1\frac{1}{2}$ per cent at $m = 1\cdot7$ under cloudless skies. A very high ratio, 19:1, of forward to backward scattering by the dust has been deduced which is, nevertheless, a minimum value, since conservative scattering was assumed. Evidently, this assumption is justified to a good approximation.

It has been argued that the loss is not significantly dependent on the albedo of the underlying surface. The agreement shown by the two independent sets of observations in Fig. 3 supports this contention. (The albedo in question is a mean value over a considerable area surrounding a station, "seen" by the radiation in the course of reflection between the surface and the sky. An appropriate radius is of the order 10 km. At the Argentine Islands, this albedo can vary substantially, from 0·8 to 0·3 say, depending on the amount of sea ice present.) It would be interesting to see if similar results could be obtained from other regions.

Two important inferences may be drawn. First, the Mount Agung dust has optical properties sufficiently different from those of a normal aerosol (see e.g. McClatchey and others, 1972) as to preclude the possibility of modelling its effects accurately by using enhanced concentrations of aerosol. Conclusions reached by such means should be treated with reserve. Secondly, if the Mount Agung dust is typical of that produced in major eruptions, it is unlikely that such events produce significant climatic changes. The loss of global radiation is of the same order as the variations arising even in cloudless conditions from other meteorological factors, and much less than the variations produced by changes in cloud cover. Moreover, the loss is highly variable, since dust concentrations show similar changes to those in ozone due to dynamic processes in the lower stratosphere. In the absence of any direct evidence that the 7 per cent difference in extra-terrestrial radiation between northern and southern mid-summer, due to the eccentricity of the Earth's orbit, leads to significantly different tropospheric conditions, the concept of dust–climate linkage is open to considerable doubt. These remarks apply to changes produced by modifying the heat balance of the surface. There remains the possibility that the re-distribution of radiation within the atmosphere may be significant but, in view of the highly directed scattering inferred above, this seems rather remote.

VII. ACKNOWLEDGEMENTS

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Successive Directors-General of the Meteorological Office have allowed the Survey to use facilities at the Kew and Lerwick Observatories for calibrating instruments and training personnel. The Meteorological Office staff involved in these operations are thanked for their whole-hearted co-operation.

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APPENDICES

APPENDIX A

ARGENTINE ISLANDS; MONTHLY SUMS OF DURATION OF BRIGHT SUNSHINE, SS, IN hr.

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM
1963	146.8	62.2	40.3	56.7	17.7	4.7	10.7	49.1	65.3	138.7	100.7	43.9	736.8
1964	83.2	75.2	64.5	29.5	22.1	19.7	19.3	84.1	61.3	17.6	164.9	120.8	762.2
1965	124.2	76.6	67.2	29.5	29.1	5.3	26.8	78.9	51.0	103.8	84.8	156.9	834.1
1966	109.4	178.9	51.5	23.6	10.6	2.8	16.4	31.2	82.5	44.1	121.3	133.8	806.1
1967	129.4	85.0	38.0	16.0	19.8	8.9	18.6	73.1	66.4	100.6	85.2	123.1	764.1
1968	148.5	89.5	82.1	16.4	30.5	6.4	9.7	32.9	44.6	105.1	148.8	161.3	875.8
1969	147.9	148.1	108.6	37.5	47.0	12.2	42.5	18.7	45.5	121.0	80.7	103.7	913.4
1970	104.7	108.8	111.5	65.8	25.0	18.7	12.1	48.6	37.7	82.6	26.4	302.2	944.1
1971	193.3	193.6	38.5	49.2	32.1	10.8	19.1	21.6	80.8	58.1	152.4	250.5	1100.0
1972	117.5	79.0	26.8	39.4	8.1	7.6	6.4	57.3	37.0	109.6	87.9	101.0	677.6
MEAN	130.5	109.7	62.9	36.4	24.2	9.7	18.2	49.5	57.2	88.1	105.3	149.7	841.4
SD	29.0	44.5	28.3	15.9	10.8	5.4	9.9	22.4	15.8	35.5	39.9	71.5	116.2
MAX	1971	1971	1970	1970	1969	1964	1969	1964	1966	1963	1964	1970	1971
MIN	1964	1963	1972	1967	1972	1966	1972	1969	1972	1964	1970	1963	1972

Sums for February in leap years have been multiplied by 28/29 (see p. 21).

ARGENTINE ISLANDS; MONTHLY SUMS OF GLOBAL SOLAR RADIATION, G, IN W hr. m.$^{-2}$

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM
1963	161577	80486	46853	24652	5867	1228	3379	19994	57775	124311	137944	139885	803951
1964	149623	90027	55935	22654	4900	1230	3180	20288	58487	105507	189658	198535	900024
1965	163163	90789	51995	22477	5572	963	3358	20103	55127	123324	167625	191797	896293
1966	140381	124257	48046	15312	5108	1249	3965	20221	63766	116952	176681	192452	908390
1967	159000	91850	43338	19027	5002	1151	3820	22704	53916	124382	135273	166123	825586
1968	156672	89754	56623	15450	5850	962	2528	16807	53861	126108	177174	189577	891366
1969	160971	107458	61940	18143	6779	1279	5324	14333	40626	108565	125362	162483	813263
1970	135312	95245	65481	23851	5359	1143	2880	19382	48384	110665	133950	220051	861703
1971	166561	115187	42891	21684	5896	948	2615	13996	50276	87799	165876	211830	885559
1972	139221	83235	41641	18932	3880	859	2679	17648	37089	102259	134303	144947	726693
MEAN	153248	96829	51474	20218	5421	1101	3373	18548	51931	112987	154385	181768	851283
SD	10707	13469	7887	3166	735	145	800	2658	7736	11760	22060	25792	55152
MAX	1971	1966	1970	1963	1969	1969	1969	1967	1966	1968	1964	1970	1966
MIN	1970	1963	1972	1966	1972	1972	1968	1971	1972	1971	1969	1963	1972

Sums for February in leap years have been multiplied by 28/29 (see p. 21).

ARGENTINE ISLANDS; MONTHLY SUMS OF DIFFUSE SOLAR RADIATION, D, IN W hr. m.$^{-2}$

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM
1963	106462	60155	37321	15991	4514	1035	2944	15110	44965	83144	101242	124370	597253
1964	120425	66137	40777	17737	4612	1126	2966	17119	47338	100441	128107	157245	704030
1965	122280	63859	35085	18015	4569	909	3009	14794	44865	89367	141159	128964	666875
1966	94186	59969	36535	11784	4385	1125	3266	15258	42801	99006	126178	130259	624752
1967	102090	61474	32803	15569	4164	1060	2916	14148	40127	90618	98676	112241	575886
1968	96745	57999	35088	12695	3770	924	2146	12291	43439	92388	119754	125368	602607
1969	107485	57685	31251	13090	4128	1023	3003	11388	30511	67814	94445	121665	543488
1970	95799	62120	37205	15081	4025	910	2565	14433	39374	84375	121956	101340	579183
1971	94403	47025	33294	13013	3936	849	2123	12222	34133	73498	104599	105796	524891
1972	93970	53595	32055	13036	3359	751	2327	11455	28308	65287	99241	103255	506639
MEAN	103384	59002	35141	14601	4146	971	2726	13822	39586	84594	113536	121050	592560
SD	10153	5177	2761	2084	375	116	384	1801	6178	11654	15051	15820	58249
MAX	1965	1964	1964	1965	1964	1964	1966	1964	1964	1964	1965	1964	1964
MIN	1972	1971	1969	1966	1972	1972	1971	1969	1972	1972	1969	1970	1972

Sums for February in leap years have been multiplied by 28/29 (see p. 21).

ARGENTINE ISLANDS; MONTHLY SUMS OF REFLECTED SOLAR RADIATION, R, IN W hr. m.$^{-2}$

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM
1963	111650	56455	36978	18951	4267	933	2590	16400	49609	109087	113329	107012	627261
1964	104532	60129	40232	17847	4044	950	2559	16933	47983	91800	148547	146914	682470
1965	109258	46328	24729	16080	3696	760	2632	16190	45607	98534	133508	143190	640512
1966	98445	81361	31628	10616	4010	920	2936	15472	49241	97535	141732	144961	678857
1967	110349	67906	33031	14800	3778	941	2642	15557	42523	102474	110612	122514	627127
1968	112885	63464	44334	12050	4518	831	2156	13488	44174	103055	143566	138233	682754
1969	115718	78917	45437	14346	4886	1002	4006	11947	33756	90904	101993	117917	620829
1970	102334	69429	48892	17888	4177	829	2387	15236	40682	92854	114630	159044	668382
1971	103632	63188	26920	15135	4138	748	1912	11596	40235	75188	130178	154240	627110
1972	89986	41032	26347	11389	2898	754	2165	14841	32219	83117	112729	113137	530614
MEAN	105879	62821	35853	14910	4041	867	2598	14766	42603	94455	125082	134716	638592
SD	7333	12114	8209	2731	502	89	548	1743	5736	9489	15520	17248	43301
MAX	1969	1966	1970	1963	1969	1969	1969	1964	1963	1963	1964	1970	1968
MIN	1972	1972	1965	1966	1972	1971	1971	1971	1972	1971	1969	1963	1972

Sums for February in leap years have been multiplied by 28/29 (see p. 21).
Monthly sum for January 1963 is estimated (see p. 21).

ARGENTINE ISLANDS; MONTHLY SUMS OF NET RADIATION, Q, IN W hr. m.$^{-2}$

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM
1963	22300	4847	-8345	-14017	-17173	-15588	-15097	-11228	-5752	-3802	4532	12730	-46593
1964	22354	7739	-9369	-15965	-12894	-16358	-21130	-17201	-4643	2061	9717	24130	-31559
1965	28019	23139	7373	-11343	-24852	-16711	-19594	-19304	-11052	-5590	11793	16164	-21958
1966	19769	7363	-4878	-12057	-21678	-15642	-17758	-11379	-7408	-1085	9114	14465	-41174
1967	20739	-2180	-8499	-11493	-18045	-17767	-20202	-21005	-12363	-14	4623	17187	-69019
1968	13288	4127	-11944	-9689	-21451	-19368	-20649	-16484	-6139	1129	11625	29732	-45823
1969	17916	4930	-12709	-13490	-28309	-21711	-24822	-11620	-11118	-7577	1680	11152	-95678
1970	11328	1464	-11853	-21623	-21332	-18882	-19528	-17444	-10720	-2088	5448	20353	-84877
1971	46964	28396	1720	-12136	-18655	-16533	-24447	-15995	-14242	-4335	12250	15197	-1816
1972	24582	22700	-1446	-14502	-21902	-19931	-19362	-19809	-8785	-3106	3787	13763	-44011
MEAN	22726	10252	-5995	-13631	-20629	-17849	-20259	-16147	-9222	-2441	7457	17487	-48251
SD	9349	9959	6310	3167	4038	1946	2719	3425	3004	2882	3667	5433	26879
MAX	1971	1971	1965	1968	1964	1963	1963	1963	1964	1964	1971	1968	1971
MIN	1970	1967	1969	1970	1969	1969	1969	1967	1971	1969	1969	1969	1969

Sums for February in leap years have been multiplied by 28/29 (see p. 21).

APPENDIX B

HALLEY BAY; MONTHLY SUMS OF DURATION OF BRIGHT SUNSHINE, *SS*, IN hr.

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM
1963	197.5	187.6	101.1	20.1	0.0	0.0	0.0	12.0	104.5	180.5	212.8	243.3	1259.4
1964	386.1	147.9	101.6	26.1	0.0	0.0	0.0	1.4	135.7	212.7	298.9	352.7	1663.1
1965	113.8	225.7	161.5	35.3	0.0	0.0	0.0	4.0	90.5	168.6	203.3	346.9	1349.6
1966	168.8	148.7	20.7	27.6	0.0	0.0	0.0	21.6	132.2	183.2	266.2	283.6	1252.6
1967	341.6	95.6	220.3	27.3	0.0	0.0	0.0	22.0	87.7	216.0	267.6	205.1	1483.2
1968	419.3	250.1	68.0	54.1	0.0	0.0	0.0	8.7	83.3	134.7	285.6	260.0	1563.8
1969	253.2	112.2	106.8	38.3	0.0	0.0	0.0	12.4	94.6	135.0	234.7	242.6	1229.8
1970	359.4	125.0	212.8	33.6	0.0	0.0	0.0	5.9	22.1	156.0	300.2	332.6	1547.6
1971	239.5	156.7	207.4	33.7	0.0	0.0	0.0	3.3	93.7	217.1	408.7	376.8	1736.9
1972	313.2	117.3	149.3	37.7	0.0	0.0	0.0	40.7	116.8	294.3	185.2	363.6	1618.1
MEAN	279.2	156.7	134.9	33.4	0.0	0.0	0.0	13.2	96.1	189.8	266.3	300.7	1470.4
SD	95.4	47.8	63.3	8.8	0.0	0.0	0.0	11.4	30.2	45.4	61.0	57.8	175.9
MAX	1968	1968	1967	1968				1972	1964	1972	1971	1971	1971
MIN	1965	1967	1966	1963				1964	1970	1968	1972	1967	1969

Sums for February in leap years have been multiplied by 28/29 (see p. 21).

HALLEY BAY; MONTHLY SUMS OF GLOBAL SOLAR RADIATION, *G*, IN W hr. m.$^{-2}$

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM
1963	196164	117182	50290	6994	34	0	0	1842	31854	103862	179920	234195	922337
1964	217625	102330	44532	7039	0	0	0	2804	35694	110666	195267	252154	968111
1965	186856	118204	59009	9030	81	0	0	2665	33285	105996	182386	253378	950890
1966	191970	106487	41689	7328	70	0	0	3264	35899	111676	194989	246489	939861
1967	221742	104112	62800	8473	0	0	0	2842	31615	108218	193773	237411	970986
1968	240171	123194	42712	8593	0	0	0	2866	32561	101354	194098	244286	989835
1969	215065	105228	49863	8316	11	0	0	3026	32100	98607	189517	238136	939869
1970	226597	111117	60773	7208	8	0	0	2754	25918	102397	195229	252289	984290
1971	204996	106969	60936	7688	23	0	0	2144	28938	106033	205747	248490	971964
1972	214702	102480	53038	7966	52	0	0	3683	32780	116622	176476	251561	959360
MEAN	211589	109730	52564	7863	28	0	0	2789	32064	106543	190740	245839	959750
SD	15752	6984	7591	683	29	0	0	492	2791	5123	8342	6682	20290
MAX	1968	1968	1967	1965				1972	1966	1972	1971	1965	1968
MIN	1965	1964	1966	1963				1963	1970	1969	1972	1963	1963

Sums for February in leap years have been multiplied by 28/29 (see p. 21).

HALLEY BAY; MONTHLY SUMS OF DIFFUSE SOLAR RADIATION, *D*, IN W hr. m.$^{-2}$

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM
1963	142401	75017	33654	5244	34	0	0	1573	19357	67702	127819	171619	644420
1964	129609	74970	34323	6034	0	0	0	2209	24148	70701	133278	172803	648075
1965	163715	86573	36674	6877	71	0	0	2202	22713	72292	130399	146354	667870
1966	152184	75589	34868	5324	63	0	0	2343	18502	60840	116718	156300	622731
1967	119238	76826	24851	5772	0	0	0	1774	21637	57005	113420	167111	587634
1968	111614	63749	33063	5083	0	0	0	2137	20761	72228	117376	161142	587153
1969	135892	76227	33080	6230	9	0	0	2276	23201	68621	128814	167652	642002
1970	118106	76725	28454	5500	8	0	0	2328	23352	66362	109404	148161	578400
1971	137134	69436	27494	5095	21	0	0	1917	18847	57628	84422	124657	526651
1972	114264	74209	28435	5212	52	0	0	2319	21152	55032	123495	124406	548576
MEAN	132416	74932	31490	5637	26	0	0	2108	21367	64841	118514	154020	605351
SD	16287	5479	3668	558	26	0	0	251	1896	6284	13610	17052	44373
MAX	1965	1965	1965	1965				1966	1964	1965	1964	1964	1965
MIN	1968	1968	1967	1968				1963	1966	1972	1971	1972	1971

Sums for February in leap years have been multiplied by 28/29 (see p. 21).

HALLEY BAY; MONTHLY SUMS OF REFLECTED SOLAR RADIATION, R, IN W hr. m.$^{-2}$

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM
1963	168345	100438	44850	6051	32	0	0	1550	26336	87761	154899	188197	778459
1964	169922	85293	36846	6234	0	0	0	2240	28240	91490	159882	206090	786237
1965	156700	94358	46365	6854	65	0	0	2188	25990	87245	149265	205733	774763
1966	157629	89940	36105	6236	53	0	0	2544	27991	89225	158179	195037	762939
1967	166643	86441	49581	6826	0	0	0	2230	24961	85956	155540	192111	770289
1968	190754	99720	36676	7017	0	0	0	2351	26265	82917	157996	199089	802785
1969	171466	86608	40110	6045	11	0	0	2250	24536	83681	157862	196410	768979
1970	183632	90867	48557	5696	8	0	0	2187	21887	85856	162053	203099	803842
1971	163104	90100	49846	6648	21	0	0	1814	24573	86939	167277	204891	795213
1972	178485	89801	45570	7020	42	0	0	3020	27661	98014	151732	207464	808809
MEAN	170668	91357	43451	6463	23	0	0	2237	25844	87908	157468	199812	785231
SD	10380	5011	5236	444	23	0	0	371	1840	4109	4840	6312	15643
MAX	1968	1963	1971	1972				1972	1964	1972	1971	1972	1972
MIN	1965	1964	1966	1970				1963	1970	1968	1965	1963	1966

Sums for February in leap years have been multiplied by 28/29 (see p. 21).

HALLEY BAY; MONTHLY SUMS OF NET RADIATION, Q, IN W hr. m.$^{-2}$

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SUM
1963	9322	598	-9574	-11865	-9650	-16220	-14976	-13509	-16433	-5434	-4357	941	-91157
1964	-624	-2499	-9674	-13112	-13658	-19523	-23639	-12759	-9939	-3346	7796	14363	-86614
1965	21735	4742	-11150	-15389	-15876	-18135	-17324	-17426	-11533	-9355	4933	11902	-72876
1966	11914	-1678	-2456	-15826	-18395	-13752	-14247	-21827	-18009	-5343	7787	16771	-75061
1967	22522	2172	-13508	-11757	-13530	-20129	-17468	-15022	-13976	-3861	14346	27300	-42911
1968	22619	5089	-3426	-12382	-14519	-11562	-17200	-13792	-13925	-522	6852	16758	-36010
1969	12604	1571	-11800	-14685	-11697	-15622	-19423	-13143	-13599	-9338	4940	12434	-77758
1970	8054	-288	-16154	-15919	-14508	-13683	-15769	-17893	-6896	-4840	7212	20362	-70322
1971	7500	-2933	-15677	-10806	-14439	-16477	-14754	-13651	-18651	-14919	-5086	5101	-114792
1972	483	-3677	-15651	-13467	-14050	-14601	-12677	-19983	-10641	-13637	9794	14616	-93491
MEAN	11613	310	-10907	-13521	-14032	-15970	-16748	-15900	-13360	-7059	5422	14055	-76099
SD	8075	2937	4594	1749	2193	2579	2943	3026	3522	4391	5672	6998	22120
MAX	1968	1968	1966	1971	1963	1968	1972	1964	1970	1968	1967	1967	1968
MIN	1964	1972	1970	1970	1966	1967	1964	1966	1971	1971	1971	1963	1971

Sums for February in leap years have been multiplied by 28/29 (see p. 21).

APPENDIX C

ARGENTINE ISLANDS; DAILY SUMS OF *SS* IN hr. *G*, *D*, *R* AND *Q* IN W hr. m.$^{-2}$

	SS				T				D				R				Q			
	MAX	MEAN	MIN	SD	MAX	MEAN	MIN	SD	MAX	MEAN	MIN	SD	MAX	MEAN	MIN	SD	MAX	MEAN	MIN	SD
JAN 1-10	19.2	4.9	0.0	7.7	9514	5658	1342	6084	6181	3717	1269	3874	6711	3920	1114	4163	2150	758	-354	887
JAN 11-20	18.0	3.6	0.0	6.1	9027	4789	1492	5171	5352	3366	1085	3511	6696	3381	1155	3634	2140	723	-128	846
JAN 21-31	17.8	4.1	0.0	6.4	8485	4434	1614	4804	5010	2959	916	3097	5604	2930	1182	3136	2773	719	-320	937
FEB 1-10	16.8	4.6	0.0	7.2	7427	4060	1132	4486	4646	2383	952	2544	4938	2615	534	2887	2586	604	-884	881
FEB 11-20	15.9	4.0	0.0	6.3	6741	3439	765	3843	4236	2092	720	2228	4557	2184	377	2413	1867	329	-546	579
FEB 21-29	14.1	2.9	0.0	4.8	5567	2745	507	3033	2918	1794	481	1887	3894	1879	232	2075	1332	125	-835	429
MAR 1-10	11.2	2.5	0.0	4.2	4777	2165	406	2460	3332	1468	403	1556	3323	1477	156	1676	1732	-19	-1112	462
MAR 11-20	12.0	1.6	0.0	3.5	4168	1532	265	1769	1980	1091	258	1162	2934	1077	97	1246	953	-164	-1238	423
MAR 21-31	10.4	2.0	0.0	3.6	3173	1318	109	1509	1572	868	106	925	2318	938	101	1086	565	-379	-1506	559
APR 1-10	9.7	1.4	0.0	2.8	2473	895	181	1033	1254	638	176	683	1518	659	124	751	156	-414	-1566	549
APR 11-20	8.4	1.5	0.0	3.0	1514	704	157	800	1089	484	154	512	1155	518	140	580	109	-491	-1754	670
APR 21-30	7.2	0.7	0.0	1.8	1163	423	84	472	636	337	78	357	793	314	42	344	10	-459	-1717	564
MAY 1-10	6.5	0.8	0.0	1.9	783	272	85	310	387	206	63	219	527	206	65	228	549	-646	-2084	827
MAY 11-20	5.9	1.0	0.0	2.1	457	177	15	202	251	130	14	138	286	128	12	140	23	-692	-2072	858
MAY 21-31	4.5	0.5	0.0	1.3	297	85	20	97	180	71	17	77	180	64	6	71	0	-659	-1902	798
JUN 1-10	3.1	0.3	0.0	0.9	118	44	7	49	81	39	7	42	74	34	7	37	0	-602	-1840	736
JUN 11-20	3.0	0.3	0.0	0.8	89	35	10	38	68	31	9	34	60	28	9	30	27	-608	-1856	734
JUN 21-30	2.8	0.3	0.0	0.8	114	31	5	37	54	27	5	30	79	25	4	28	-8	-575	-1528	675
JUL 1-10	3.7	0.5	0.0	1.1	230	61	11	70	117	49	11	54	92	43	0	47	-26	-760	-1844	869
JUL 11-20	4.0	0.4	0.0	1.0	204	85	7	96	135	71	7	76	166	65	7	72	-29	-611	-1375	686
JUL 21-31	5.1	0.8	0.0	1.6	452	175	30	195	345	139	29	148	313	137	23	149	17	-595	-1467	685
AUG 1-10	6.7	1.2	0.0	2.2	637	315	111	339	396	250	108	261	508	257	102	273	51	-587	-1499	683
AUG 11-20	8.1	1.6	0.0	2.8	1031	555	137	590	744	416	131	434	826	449	127	472	117	-498	-1426	620
AUG 21-31	8.7	1.9	0.0	3.3	1743	895	190	972	1210	651	190	679	1219	701	169	740	195	-482	-1547	592
SEP 1-10	9.2	2.0	0.0	3.4	2549	1307	387	1399	1665	951	381	992	1791	1059	371	1111	187	-369	-1147	481
SEP 11-20	9.8	1.8	0.0	3.5	3119	1653	286	1769	2058	1254	263	1314	2254	1362	268	1432	232	-301	-1349	419
SEP 21-30	11.6	1.9	0.0	3.5	3995	2233	612	2349	2594	1754	601	1820	3251	1839	529	1916	272	-252	-1275	413
OCT 1-10	12.2	3.0	0.0	4.9	4758	3000	567	3142	3807	2123	550	2238	3739	2488	493	2582	405	-221	-1150	413
OCT 11-20	13.1	1.8	0.0	3.3	5885	3422	1120	3541	4152	2851	1114	2924	4802	2902	1056	2987	481	-15	-922	221
OCT 21-31	15.5	3.7	0.0	5.9	6825	4434	1775	4585	4918	3169	739	3313	5370	3687	1619	3784	700	-7	-1014	332
NOV 1-10	16.2	4.4	0.0	6.5	7735	4978	2093	5210	5343	3361	1170	3484	6071	4125	1951	4278	858	84	-674	286
NOV 11-20	15.5	2.7	0.0	4.9	8368	5015	943	5276	5718	3917	933	4060	6578	4125	845	4302	1152	252	-229	377
NOV 21-30	18.5	3.4	0.0	5.9	8952	5445	2320	5717	6281	4075	973	4224	6576	4258	1977	4423	1235	410	-435	545
DEC 1-10	18.7	3.4	0.0	5.7	9455	5572	2124	5872	6630	4220	1501	4391	6653	4286	1706	4468	1219	388	-399	502
DEC 11-20	19.7	5.7	0.0	8.6	9838	6337	2197	6668	6420	4007	1081	4224	7344	4644	1748	4841	1924	593	-466	725
DEC 21-31	19.8	5.3	0.0	8.5	9880	5698	1550	6142	6891	3525	1031	3765	6874	4129	1350	4394	2080	698	-45	839

APPENDIX D

HALLEY BAY; DAILY SUMS OF *SS* IN hr. *G*, *D*, *R* AND *Q* IN W hr. m.$^{-2}$

	SS				T				D				R				Q			
	MAX	MEAN	MIN	SD	MAX	MEAN	MIN	SD	MAX	MEAN	MIN	SD	MAX	MEAN	MIN	SD	MAX	MEAN	MIN	SD
JAN 1-10	24.0	9.2	0.0	12.4	10149	7505	4585	7653	7027	4716	1703	4911	8099	6046	4081	6124	1085	466	-321	586
JAN 11-20	24.0	9.3	0.0	12.5	9852	6986	4220	7121	6270	4405	1187	4618	7398	5628	3654	5699	1228	391	-464	529
JAN 21-31	24.0	8.6	0.0	12.0	8775	6062	3896	6203	5475	3746	1301	3928	6748	4903	3366	4979	1363	277	-816	474
FEB 1-10	24.0	6.1	0.0	9.8	7582	4709	2554	4875	4604	3202	1102	3324	5796	3910	2280	4012	996	149	-758	359
FEB 11-20	20.8	5.3	0.0	8.5	6130	3817	2388	3950	4255	2687	870	2750	4679	3186	2120	3264	610	-8	-811	288
FEB 21-29	18.2	5.3	0.0	7.8	4875	3090	1474	3199	4114	2025	913	2121	3834	2575	1369	2643	484	-133	-1046	378
MAR 1-10	16.0	5.7	0.0	8.1	3931	2479	1109	2587	3743	1426	548	1511	3169	2040	985	2109	370	-325	-1260	508
MAR 11-20	12.1	4.6	0.0	6.3	2664	1710	843	1778	1749	1004	410	1048	2224	1422	780	1471	415	-372	-1349	537
MAR 21-31	11.3	2.9	0.0	4.8	1862	971	440	1034	1354	654	295	680	1469	803	393	846	318	-358	-1161	503
APR 1-10	8.8	1.7	0.0	3.0	1047	511	229	549	713	365	198	379	832	423	178	450	238	-380	-1499	532
APR 11-20	6.6	1.0	0.0	2.2	589	215	69	242	330	158	65	169	493	176	60	196	160	-436	-1324	570
APR 21-30	4.9	0.6	0.0	1.3	247	61	0	79	117	41	0	50	189	48	0	62	127	-535	-1310	665
MAY 1-10					30	3	0	7	22	3	0	6	23	2	0	5	173	-463	-1510	564
MAY 11-20																	307	-466	-1151	566
MAY 21-31																	198	-431	-1677	545
JUN 1-10																	349	-526	-1571	624
JUN 11-20																	215	-545	-1460	649
JUN 21-30																	367	-526	-1499	664
JUL 1-10																	173	-599	-1990	711
JUL 11-20																	232	-512	-1470	622
JUL 21-31																	288	-512	-1596	661
AUG 1-10					34	3	0	6	34	2	0	6	25	2	0	5	199	-499	-1553	625
AUG 11-20	2.9	0.2	0.0	0.7	154	44	0	54	90	35	0	40	118	36	0	43	251	-557	-1370	668
AUG 21-31	7.2	1.0	0.0	2.0	559	211	43	235	334	158	38	169	441	169	26	188	369	-485	-1626	633
SEP 1-10	9.4	2.1	0.0	3.5	1216	530	245	568	683	376	167	390	782	424	201	446	888	-457	-1271	644
SEP 11-20	10.4	3.7	0.0	5.2	2288	1053	515	1099	1534	682	271	711	1354	840	453	867	314	-508	-1398	665
SEP 21-30	11.5	3.8	0.0	5.6	2776	1624	759	1672	1594	1079	413	1119	2017	1320	718	1349	232	-371	-1292	513
OCT 1-10	14.6	4.3	0.0	6.4	3777	2343	1081	2413	2282	1535	526	1600	2979	1930	1019	1977	752	-323	-1329	519
OCT 11-20	17.2	5.4	0.0	7.6	4856	3268	1871	3348	3222	2159	743	2222	4029	2701	1724	2754	647	-183	-1070	382
OCT 21-31	20.9	8.4	0.0	10.6	6322	4585	2506	4662	4069	2537	838	2693	5109	3782	2321	3829	470	-182	-1206	401
NOV 1-10	24.0	7.9	0.0	11.1	7758	5397	3503	5501	5243	3426	1168	3582	5908	4466	3084	4520	798	54	-818	346
NOV 11-20	24.0	10.4	0.0	13.6	8666	6595	3729	6715	5804	3687	1248	3951	6729	5422	3459	5486	711	126	-727	318
NOV 21-30	24.0	8.3	0.0	11.5	9708	7082	4915	7178	6737	4738	1400	4957	7484	5859	4528	5908	913	363	-372	466
DEC 1-10	24.0	11.7	0.0	14.5	10088	8031	5160	8132	6861	4528	1415	4810	8174	6574	4690	6627	988	363	-296	470
DEC 11-20	24.0	8.9	0.0	12.1	10300	7920	5233	8030	7222	5124	1314	5394	8309	6459	4468	6520	1126	454	-280	543
DEC 21-31	24.0	8.6	0.0	11.7	10127	7848	5295	7954	7285	5227	1622	5452	8033	6316	4475	6372	1304	535	-105	632

APPENDIX E

ARGENTINE ISLANDS; HOURLY MEAN DURATION OF BRIGHT SUNSHINE, *SS*, IN min.

	MEAN HOURLY VALUES FOR THE HOUR BEGINNING AT L.A.T.																							
HOUR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
JAN 1-10		0	1	9	9	11	14	15	16	17	17	19	23	22	19	20	19	18	16	14	11	6	0	
JAN 11-20		0	0	4	7	8	9	10	12	12	15	17	17	18	17	16	15	13	10	9	7	3	0	
JAN 21-31			0	3	7	9	12	14	15	16	16	16	18	19	18	16	16	16	14	11	8	1		
FEB 1-10			0	0	8	10	14	17	19	20	22	20	21	21	21	21	18	17	14	10	4	0		
FEB 11-20				0	2	7	12	16	18	19	20	21	19	19	18	20	20	14	11	6	0			
FEB 21-29					0	6	9	14	15	16	17	14	14	16	14	14	12	9	5	0				
MAR 1-10					0	0	4	9	12	14	16	16	15	12	14	14	13	8	2	0				
MAR 11-20						0	2	9	10	8	8	9	9	10	10	9	7	4	0					
MAR 21-31						0	0	7	11	13	14	14	13	14	13	12	8	1	0					
APR 1-10							0	2	6	9	11	12	11	10	9	8	4	0						
APR 11-20							0	0	8	12	14	14	13	12	9	9	1	0						
APR 21-30								0	2	5	8	7	7	8	6	1	0							
MAY 1-10								0	0	5	6	10	10	8	8	2	0							
MAY 11-20									0	5	13	13	13	13	6	0								
MAY 21-31									0	0	6	8	8	7	1	0								
JUN 1-10										0	2	8	7	4	0									
JUN 11-20										0	1	8	9	3	0									
JUN 21-30										0	1	6	7	3	0									
JUL 1-10										0	4	11	11	6	0									
JUL 11-20										0	4	8	8	4	1									
JUL 21-31									0	1	9	12	12	11	3	0								
AUG 1-10									0	8	12	15	16	14	10	1								
AUG 11-20								0	2	12	14	16	17	17	14	6	0							
AUG 21-31							0	0	7	12	16	16	17	15	16	12	2	0						
SEP 1-10							0	2	9	10	13	16	17	15	16	14	6	0						
SEP 11-20						0	0	5	10	11	12	13	14	13	13	12	8	1	0					
SEP 21-30						0	1	6	8	12	14	12	11	11	13	10	10	5	0					
OCT 1-10					0	0	7	13	17	16	17	17	18	17	17	15	13	11	2	0				
OCT 11-20					0	2	4	7	9	8	9	11	13	13	11	9	5	4	1	0				
OCT 21-31				0	2	7	11	15	15	17	17	18	18	19	18	19	18	13	11	4	0			
NOV 1-10			0	0	4	8	12	12	14	18	21	24	23	23	24	20	19	16	14	9	1	0		
NOV 11-20			0	0	2	5	7	11	12	13	15	14	13	12	14	13	12	10	6	3	2	0		
NOV 21-30		0	0	3	4	6	9	11	13	16	16	17	16	14	14	13	12	11	11	9	8	2	0	
DEC 1-10		0	0	4	7	7	11	11	12	16	17	15	14	12	14	14	11	11	11	8	7	4	0	
DEC 11-20		0	2	9	9	11	15	19	21	20	22	22	23	21	21	21	20	20	19	18	16	13	2	
DEC 21-31		0	4	10	12	15	15	18	20	20	19	18	18	20	20	18	19	18	16	14	12	9	1	

Argentine Islands; hourly mean values of global solar radiation, G, in W m.$^{-2}$

HOUR	MEAN HOURLY VALUES FOR THE HOUR BEGINNING AT L.A.T.																						
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
JAN 1-10		3	15	45	85	151	230	313	401	467	517	547	555	538	474	414	331	248	165	96	46	15	2	
JAN 11-20		1	7	29	70	125	193	259	337	397	461	497	508	470	409	342	268	192	120	68	30	7	1	
JAN 21-31			2	17	53	102	170	242	315	381	421	450	460	441	391	330	264	196	120	58	19	3		
FEB 1-10			0	6	33	82	152	225	300	370	413	432	443	411	372	304	229	156	89	36	7	0		
FEB 11-20				1	16	60	120	194	260	318	360	382	383	363	319	272	196	122	58	16	1			
FEB 21-29					5	33	86	149	217	274	312	323	320	315	254	201	143	80	30	4				
MAR 1-10					0	12	50	103	159	220	267	275	271	246	216	166	111	55	13	0				
MAR 11-20						3	25	71	117	153	180	200	206	196	168	118	67	27	2					
MAR 21-31						0	8	42	90	140	173	193	196	181	144	95	45	10	0					
APR 1-10							1	18	54	92	125	148	148	127	97	60	23	2						
APR 11-20							0	7	36	78	110	125	124	107	73	36	7	0						
APR 21-30								1	15	44	72	83	81	69	43	14	1							
MAY 1-10								0	5	23	44	62	62	47	24	4	0							
MAY 11-20									1	12	32	44	44	31	11	1								
MAY 21-31									0	3	15	24	24	15	4	0								
JUN 1-10										1	7	14	13	7	1									
JUN 11-20										0	5	11	12	5	0									
JUN 21-30										0	5	10	11	5	0									
JUL 1-10										2	9	18	19	10	2									
JUL 11-20										3	14	24	24	15	4									
JUL 21-31									1	10	31	45	46	31	11	1								
AUG 1-10									4	26	53	71	71	56	28	5								
AUG 11-20								1	16	54	88	110	115	93	58	19	1							
AUG 21-31							0	7	43	94	135	160	161	139	98	49	9	0						
SEP 1-10							2	25	78	133	186	215	214	187	145	89	30	2						
SEP 11-20						0	9	51	111	172	220	247	253	225	175	120	59	11	0					
SEP 21-30						3	30	90	156	228	279	308	309	285	240	169	97	35	3					
OCT 1-10					0	12	64	142	225	296	352	388	388	361	303	226	149	75	18	0				
OCT 11-20					3	33	91	170	252	325	383	424	433	399	341	253	174	98	36	4				
OCT 21-31				1	18	68	144	239	325	406	470	508	507	474	418	349	253	156	77	21	1			
NOV 1-10			0	7	41	101	178	264	352	436	502	541	534	520	476	377	288	191	113	47	9	0		
NOV 11-20			2	16	54	115	190	287	366	438	498	522	521	497	449	371	284	200	122	61	20	2		
NOV 21-30		0	6	31	77	140	219	302	386	464	515	549	550	514	471	400	312	228	153	84	36	9	0	
DEC 1-10		2	13	40	88	155	231	311	390	467	530	539	545	514	483	406	307	229	163	94	47	16	2	
DEC 11-20		3	19	55	102	174	267	362	448	525	584	607	598	566	525	459	363	278	195	120	60	23	5	
DEC 21-31		4	18	52	101	169	241	333	415	479	521	550	531	514	460	392	326	245	171	103	51	19	4	

ARGENTINE ISLANDS; HOURLY MEAN VALUES OF DIFFUSE SOLAR RADIATION, D, IN W m.$^{-2}$

	MEAN HOURLY VALUES FOR THE HOUR BEGINNING AT L.A.T.																							
HOUR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
JAN 1-10		3	13	34	63	107	154	211	263	318	342	359	346	335	310	262	216	160	108	67	33	12	2	
JAN 11-20		0	6	24	55	96	147	191	246	289	326	336	338	317	277	237	187	130	85	49	22	6	1	
JAN 21-31			2	14	40	75	120	162	212	258	284	304	292	277	251	220	176	132	82	42	14	2		
FEB 1-10			0	5	24	57	96	132	172	208	227	253	262	241	208	172	134	98	60	27	6	0		
FEB 11-20				1	13	43	82	123	155	188	210	228	228	212	193	163	119	79	41	12	1			
FEB 21-29					4	25	61	94	135	173	197	211	207	201	168	135	98	59	23	4				
MAR 1-10					0	10	39	74	114	149	175	183	176	168	143	112	75	39	10	0				
MAR 11-20						2	20	49	80	108	127	142	147	140	120	84	49	21	2					
MAR 21-31						0	7	31	60	88	108	123	129	120	96	64	33	8	0					
APR 1-10							1	14	39	64	85	101	106	92	70	46	19	2						
APR 11-20							0	6	26	51	70	83	86	75	53	28	6	0						
APR 21-30								1	12	35	55	66	66	54	34	12	1							
MAY 1-10								0	4	18	34	44	45	36	19	4	0							
MAY 11-20									1	10	24	31	31	23	9	1								
MAY 21-31									0	3	12	19	20	13	4	0								
JUN 1-10										1	6	12	11	6	1									
JUN 11-20										0	5	10	11	5	0									
JUN 21-30										0	4	9	9	5	0									
JUL 1-10										2	8	15	15	8	2									
JUL 11-20										3	12	19	20	13	4									
JUL 21-31									1	9	24	34	35	25	9	1								
AUG 1-10									4	22	43	55	54	44	24	5								
AUG 11-20								1	14	41	66	80	83	70	46	16	1							
AUG 21-31							0	6	34	69	96	114	113	101	72	38	8	0						
SEP 1-10							2	21	61	101	133	152	153	134	103	65	24	2						
SEP 11-20						0	8	42	88	134	168	186	187	168	128	90	47	10	0					
SEP 21-30						2	26	74	126	175	216	241	243	224	183	132	77	29	3					
OCT 1-10					0	11	47	99	157	207	245	274	270	253	216	164	111	56	14	0				
OCT 11-20					3	29	79	142	206	277	325	343	342	325	283	217	155	88	34	4				
OCT 21-31				1	15	55	109	170	230	287	336	362	361	334	292	242	179	118	61	18	1			
NOV 1-10			0	6	34	81	135	199	260	303	322	335	347	334	303	249	194	133	81	37	8	0		
NOV 11-20			2	14	49	99	156	225	284	330	370	391	402	392	350	290	227	161	103	54	18	2		
NOV 21-30		0	6	26	63	113	170	239	294	336	374	399	406	382	350	296	234	172	115	65	29	7	0	
DEC 1-10		2	11	35	73	125	178	245	304	339	375	399	411	398	362	302	235	173	124	75	39	14	2	
DEC 11-20		3	16	41	78	129	186	235	292	334	369	381	359	348	326	278	213	166	119	74	40	16	4	
DEC 21-31		3	14	37	68	107	151	200	241	286	324	346	343	317	279	239	199	147	105	68	34	14	4	

Argentine Islands; hourly mean values of reflected solar radiation, R, in W m.$^{-2}$

	MEAN HOURLY VALUES FOR THE HOUR BEGINNING AT L.A.T.																							
HOUR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
JAN 1-10		2	10	32	59	102	154	208	266	310	348	371	377	372	335	293	243	183	127	76	36	11	2	
JAN 11-20		0	5	22	52	91	139	185	237	274	317	341	345	326	286	243	197	143	92	54	24	6	0	
JAN 21-31			2	11	34	66	108	152	199	241	271	292	300	292	261	225	185	140	89	46	15	2		
FEB 1-10			0	4	21	52	96	142	188	232	257	270	280	263	241	203	158	111	66	28	5	0		
FEB 11-20				1	10	36	73	118	159	195	222	239	241	230	205	179	134	87	43	11	0			
FEB 21-29					3	22	57	98	144	184	208	217	217	216	178	145	106	61	22	3				
MAR 1-10					0	8	34	66	105	143	175	185	183	169	152	121	83	42	10	0				
MAR 11-20						2	18	48	79	105	125	140	144	137	120	87	51	21	2					
MAR 21-31						0	6	30	63	95	119	135	139	130	107	72	35	7	0					
APR 1-10							1	13	38	65	89	107	110	96	74	47	18	2						
APR 11-20							0	5	25	54	78	91	92	81	57	29	6	0						
APR 21-30								1	11	32	51	61	61	52	33	11	1							
MAY 1-10								0	4	17	33	46	47	37	19	4	0							
MAY 11-20									1	9	23	32	31	23	9	1								
MAY 21-31									0	3	11	18	18	12	3	0								
JUN 1-10										1	6	10	10	6	1									
JUN 11-20										0	4	9	10	4	0									
JUN 21-30										0	4	8	9	4	0									
JUL 1-10										1	7	13	13	7	2									
JUL 11-20										3	11	18	19	12	3									
JUL 21-31									1	8	24	35	36	25	9	1								
AUG 1-10									4	21	42	57	58	47	24	4								
AUG 11-20								1	13	42	69	89	93	77	49	16	1							
AUG 21-31							0	5	33	71	103	124	127	110	79	40	7	0						
SEP 1-10							1	20	61	105	147	172	175	155	121	75	26	2						
SEP 11-20						0	7	41	90	139	178	203	208	187	148	102	50	9	0					
SEP 21-30						2	24	71	124	183	226	253	257	239	202	143	83	30	3					
OCT 1-10					0	10	50	113	181	241	288	320	325	304	256	193	127	64	15	0				
OCT 11-20					3	28	76	142	209	272	321	357	366	340	293	221	152	86	33	4				
OCT 21-31				1	14	56	117	194	265	332	386	419	421	395	351	296	218	136	68	18	1			
NOV 1-10			0	6	34	83	144	214	284	352	409	445	443	433	398	319	246	166	99	41	8	0		
NOV 11-20			1	13	45	94	154	231	296	356	405	427	428	411	371	308	238	169	105	53	17	2		
NOV 21-30		0	4	23	58	107	167	233	298	357	399	426	427	403	372	317	249	185	125	70	30	7	0	
DEC 1-10		1	9	30	67	117	174	236	298	356	401	414	417	395	373	315	241	181	130	76	38	13	2	
DEC 11-20		2	14	40	75	128	193	260	323	379	421	438	435	413	385	338	271	211	151	95	48	19	4	
DEC 21-31		3	13	39	73	121	172	237	294	340	370	390	379	369	334	289	243	187	133	83	41	15	3	

ARGENTINE ISLANDS; HOURLY MEAN VALUES OF NET RADIATION, Q, IN W m.$^{-2}$

	MEAN HOURLY VALUES FOR THE HOUR BEGINNING AT L.A.T.																							
HOUR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
JAN 1-10	-28	-28	-26	-20	-8	9	31	56	81	103	120	128	130	120	96	73	44	19	-5	-20	-28	-31	-29	-28
JAN 11-20	-26	-25	-24	-17	-5	8	27	48	71	94	114	124	127	115	92	65	39	17	-2	-15	-23	-26	-28	-27
JAN 21-31	-25	-25	-25	-21	-9	6	27	50	77	100	113	124	124	114	94	69	42	17	-5	-20	-26	-28	-27	-26
FEB 1-10	-29	-28	-27	-27	-19	-3	19	44	70	95	113	121	122	109	89	63	34	9	-11	-25	-29	-29	-29	-29
FEB 11-20	-26	-26	-26	-27	-25	-12	6	28	50	70	85	91	91	83	66	48	20	-2	-19	-27	-30	-30	-30	-30
FEB 21-29	-24	-25	-26	-26	-23	-14	0	17	34	52	62	69	65	59	39	19	-1	-14	-22	-26	-25	-23	-23	-21
MAR 1-10	-23	-23	-22	-22	-23	-20	-10	5	22	39	53	53	49	42	30	11	-6	-20	-25	-27	-26	-25	-24	-24
MAR 11-20	-23	-22	-22	-22	-22	-20	-13	-2	8	17	23	28	29	25	15	2	-10	-17	-21	-23	-24	-23	-23	-23
MAR 21-31	-24	-24	-24	-25	-25	-25	-22	-15	-7	2	10	11	12	4	-5	-15	-24	-28	-28	-27	-26	-26	-24	-24
APR 1-10	-22	-22	-23	-22	-22	-22	-20	-17	-13	-5	1	3	3	-4	-11	-16	-22	-25	-25	-28	-27	-25	-24	-23
APR 11-20	-22	-23	-23	-24	-25	-24	-24	-24	-18	-10	-7	-6	-7	-13	-17	-22	-25	-26	-27	-27	-26	-24	-23	-22
APR 21-30	-23	-23	-23	-22	-22	-23	-23	-24	-20	-13	-8	-6	-6	-12	-15	-18	-20	-21	-23	-23	-22	-21	-23	-24
MAY 1-10	-30	-29	-30	-31	-32	-31	-30	-31	-28	-25	-22	-20	-20	-22	-25	-15	-27	-26	-27	-28	-28	-29	-30	-31
MAY 11-20	-32	-32	-31	-31	-32	-31	-31	-30	-30	-28	-24	-22	-24	-25	-28	-29	-29	-28	-28	-30	-30	-30	-29	-29
MAY 21-31	-27	-29	-28	-27	-26	-27	-29	-28	-26	-28	-26	-24	-25	-27	-28	-28	-29	-28	-28	-28	-28	-27	-28	-28
JUN 1-10	-20	-22	-24	-24	-25	-26	-26	-24	-25	-26	-25	-24	-25	-25	-26	-27	-27	-28	-29	-27	-27	-26	-24	-23
JUN 11-20	-22	-24	-23	-24	-26	-27	-28	-26	-25	-25	-24	-24	-24	-27	-26	-25	-27	-26	-27	-28	-27	-26	-25	-23
JUN 21-30	-23	-24	-24	-25	-26	-26	-25	-25	-24	-24	-23	-24	-23	-23	-23	-24	-26	-25	-24	-24	-23	-24	-23	-21
JUL 1-10	-31	-31	-30	-30	-30	-32	-32	-33	-31	-31	-32	-31	-31	-31	-33	-33	-32	-33	-33	-33	-33	-33	-31	-32
JUL 11-20	-25	-25	-25	-26	-27	-26	-27	-25	-27	-29	-26	-24	-23	-24	-24	-26	-26	-26	-27	-26	-25	-24	-25	-26
JUL 21-31	-23	-24	-26	-26	-26	-26	-28	-27	-27	-24	-22	-23	-20	-20	-23	-25	-27	-26	-25	-26	-26	-24	-25	-24
AUG 1-10	-25	-24	-25	-25	-23	-23	-24	-24	-26	-23	-21	-21	-22	-25	-29	-29	-30	-27	-24	-23	-23	-22	-24	-25
AUG 11-20	-21	-23	-22	-22	-23	-22	-21	-23	-21	-16	-12	-13	-14	-19	-23	-23	-24	-23	-25	-25	-22	-21	-21	-21
AUG 21-31	-24	-24	-22	-20	-23	-23	-22	-21	-18	-13	-8	-4	-8	-12	-17	-22	-25	-25	-26	-27	-25	-25	-25	-25
SEP 1-10	-18	-20	-20	-20	-19	-20	-20	-19	-10	-1	5	6	4	-6	-14	-19	-24	-26	-25	-24	-22	-20	-20	-19
SEP 11-20	-19	-20	-20	-22	-20	-18	-18	-14	-5	3	10	13	9	4	-6	-15	-20	-23	-21	-19	-19	-19	-21	-21
SEP 21-30	-23	-21	-21	-23	-23	-20	-16	-6	3	12	18	22	19	14	4	-6	-17	-23	-24	-25	-25	-24	-24	-23
OCT 1-10	-23	-21	-20	-21	-21	-21	-15	-4	8	16	22	24	20	14	6	-6	-15	-22	-25	-25	-23	-23	-23	-23
OCT 11-20	-15	-17	-16	-15	-14	-13	-6	4	15	26	31	33	32	26	18	5	-2	-10	-16	-18	-17	-17	-16	-15
OCT 21-31	-23	-21	-20	-22	-19	-12	-2	11	24	36	43	48	43	36	27	12	-3	-15	-22	-26	-27	-26	-25	-24
NOV 1-10	-24	-23	-23	-21	-18	-11	5	20	34	48	57	59	53	46	35	17	2	-13	-23	-26	-28	-28	-27	-26
NOV 11-20	-21	-21	-19	-16	-11	-2	9	24	38	50	58	62	61	55	46	32	15	2	-9	-16	-21	-23	-22	-20
NOV 21-30	-22	-22	-23	-19	-11	1	17	33	50	65	78	85	83	76	65	46	27	9	-6	-18	-26	-26	-27	-24
DEC 1-10	-30	-28	-24	-20	-11	3	16	34	49	67	81	83	84	76	65	47	25	9	-4	-17	-27	-29	-30	-31
DEC 11-20	-28	-28	-24	-20	-10	7	26	49	69	89	105	112	106	96	84	63	35	14	-7	-22	-30	-33	-31	-29
DEC 21-31	-26	-25	-25	-17	-4	14	33	57	80	100	113	122	113	104	84	61	38	12	-7	-18	-26	-28	-28	-28

APPENDIX F

HALLEY BAY; HOURLY MEAN DURATION OF BRIGHT SUNSHINE, *SS*, IN min.

	MEAN HOURLY VALUES FOR THE HOUR BEGINNING AT L.A.T.																							
HOUR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
JAN 1-10	19	19	20	19	18	18	21	23	24	26	26	24	26	26	26	26	27	26	24	24	23	23	22	20
JAN 11-20	18	17	17	18	19	20	22	23	23	26	27	28	28	26	27	26	26	27	27	27	24	24	20	19
JAN 21-31	17	15	16	16	18	20	21	24	25	24	25	25	24	27	27	27	24	24	24	21	19	19	18	15
FEB 1-10	7	8	10	11	12	15	17	19	20	20	22	19	19	19	17	16	19	18	17	16	15	12	9	9
FEB 11-20	2	3	6	11	13	15	16	18	18	20	20	20	18	21	20	20	20	17	17	13	9	4	1	0
FEB 21-29			0	7	12	14	15	19	20	22	23	25	23	23	23	21	19	19	17	11	5	0		
MAR 1-10				0	11	17	22	25	27	29	28	27	26	25	26	26	21	19	11	4	0			
MAR 11-20					0	4	11	20	24	26	28	27	27	26	26	24	22	12	1	0				
MAR 21-31						0	2	12	16	18	19	21	20	19	19	16	8	1	0					
APR 1-10							0	1	7	12	16	17	17	15	13	5	0	0						
APR 11-20								0	2	9	11	12	11	9	6	1	0							
APR 21-30									0	1	6	11	11	5	0	0								
MAY 1-10											0	0	0	0										
MAY 11-20																								
MAY 21-31																								
JUN 1-10																								
JUN 11-20																								
JUN 21-30																								
JUL 1-10																								
JUL 11-20																								
JUL 21-31																								
AUG 1-10										0	0	0	0	0	0									
AUG 11-20									0	0	2	5	5	1	0	0								
AUG 21-31								0	1	6	11	14	13	8	5	1	0							
SEP 1-10							0	1	8	14	18	20	22	21	16	8	1	0						
SEP 11-20						0	2	12	22	26	29	28	27	27	24	17	7	0	0					
SEP 21-30					0	1	5	15	21	24	25	27	26	25	23	21	14	3	0	0				
OCT 1-10				0	3	9	13	20	21	21	23	23	22	24	21	20	18	12	8	1	0			
OCT 11-20			0	3	9	14	18	23	24	23	24	23	25	24	24	22	21	19	16	9	3	0		
OCT 21-31	0	2	7	13	18	22	25	27	28	31	34	33	36	35	32	31	30	28	24	23	16	7	2	1
NOV 1-10	9	11	13	14	16	16	18	23	25	28	30	31	29	26	24	23	25	22	21	19	17	15	11	10
NOV 11-20	16	19	23	24	25	26	26	28	26	29	30	32	33	33	32	32	30	29	29	27	25	21	17	15
NOV 21-30	14	15	17	19	19	19	20	23	23	23	23	23	24	25	25	25	26	23	21	19	19	19	17	17
DEC 1-10	23	23	26	28	28	27	28	29	30	32	31	31	33	33	34	33	35	33	30	29	28	27	27	26
DEC 11-20	19	18	19	19	20	20	22	24	25	24	26	27	27	26	25	24	23	22	22	21	19	19	20	18
DEC 21-31	14	16	18	17	19	19	23	24	24	25	27	28	27	26	25	25	23	23	22	20	20	19	17	15

HALLEY BAY; HOURLY MEAN VALUES OF GLOBAL SOLAR RADIATION, G, IN W $m.^{-2}$

	MEAN HOURLY VALUES FOR THE HOUR BEGINNING AT L.A.T.																							
HOUR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
JAN 1-10	90	100	123	155	200	249	320	387	453	509	541	563	567	549	513	463	402	336	279	223	167	129	101	88
JAN 11-20	71	81	99	130	178	235	298	363	422	484	526	546	542	523	489	436	378	320	255	198	146	112	84	70
JAN 21-31	44	51	73	105	148	201	264	333	390	432	472	492	489	479	446	388	330	273	213	159	110	76	53	42
FEB 1-10	19	27	41	64	100	147	199	263	313	364	398	412	415	399	361	316	266	210	150	103	65	38	22	16
FEB 11-20	3	6	16	36	68	111	159	215	263	309	340	359	359	353	316	276	221	169	115	67	35	14	5	2
FEB 21-29			2	12	35	72	122	175	226	270	302	318	321	306	269	229	179	124	76	36	11	2		
MAR 1-10				1	13	44	89	141	189	236	263	279	280	259	229	185	133	84	40	12	1			
MAR 11-20					1	12	42	86	130	172	203	219	217	201	166	129	82	40	10	1				
MAR 21-31						0	10	36	69	100	126	144	146	126	101	69	34	9	0					
APR 1-10							0	8	29	55	76	91	88	74	53	28	7	0						
APR 11-20								0	6	21	35	46	44	35	21	6	0							
APR 21-30									0	3	10	17	17	11	3	0								
MAY 1-10											0	1	1	0										
MAY 11-20																								
MAY 21-31																								
JUN 1-10																								
JUN 11-20																								
JUN 21-30																								
JUL 1-10																								
JUL 11-20																								
JUL 21-31																								
AUG 1-10										0	0	1	1	0	0									
AUG 11-20									0	1	7	13	13	8	2	0								
AUG 21-31								0	5	19	35	46	47	36	18	4	0							
SEP 1-10							0	7	28	55	76	92	96	82	58	29	7	0						
SEP 11-20						0	8	37	74	110	140	157	156	142	114	72	35	8	0					
SEP 21-30					0	7	34	76	119	158	192	214	213	202	172	122	77	33	6	0				
OCT 1-10				0	8	34	78	129	177	221	252	269	269	258	223	177	127	77	34	8	0			
OCT 11-20			1	10	35	73	126	186	240	288	323	338	342	324	293	241	186	132	81	39	11	1		
OCT 21-31	1	5	16	41	82	134	197	261	320	372	408	428	437	418	378	326	266	200	139	87	45	18	5	2
NOV 1-10	18	27	44	74	116	169	228	299	362	411	455	479	478	456	415	358	304	239	173	119	77	47	29	20
NOV 11-20	47	59	84	121	169	227	287	353	408	467	512	532	535	511	472	426	361	295	235	179	126	84	60	47
NOV 21-30	67	76	101	138	181	240	306	378	443	492	530	548	549	535	495	442	380	321	255	192	146	110	85	72
DEC 1-10	95	105	129	171	225	281	345	415	484	537	572	591	597	578	547	490	431	370	300	235	184	142	112	96
DEC 11-20	100	110	136	172	224	277	343	410	471	529	568	599	593	575	533	476	414	345	286	230	180	136	113	100
DEC 21-31	93	104	131	169	213	267	344	414	472	521	565	585	585	568	531	481	416	350	287	230	178	139	109	97

HALLEY BAY; HOURLY MEAN VALUES OF DIFFUSE SOLAR RADIATION, D, IN W m.$^{-2}$

	MEAN HOURLY VALUES FOR THE HOUR BEGINNING AT L.A.T.																							
HOUR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
JAN 1-10	62	71	85	106	139	176	216	249	285	317	337	348	347	336	313	282	245	198	165	133	101	81	66	59
JAN 11-20	51	58	72	92	122	159	199	237	266	300	324	339	340	315	296	263	230	193	153	118	93	75	59	51
JAN 21-31	32	38	52	75	102	131	173	207	233	265	292	298	299	281	256	227	196	164	128	101	74	53	38	30
FEB 1-10	15	20	31	48	71	100	131	172	200	234	254	280	282	274	256	222	180	145	106	74	47	28	18	13
FEB 11-20	2	5	13	27	52	83	116	154	191	217	234	246	256	244	215	187	152	114	82	51	28	11	4	2
FEB 21-29			1	10	28	55	89	123	151	176	194	195	199	191	166	151	122	85	53	26	9	2		
MAR 1-10				1	10	29	55	82	103	125	142	155	158	153	130	107	84	54	28	9	1			
MAR 11-20					1	9	29	56	77	96	113	125	125	114	96	75	52	27	8	1				
MAR 21-31						0	7	25	46	66	83	93	96	85	70	49	26	7	0					
APR 1-10							0	7	21	38	52	63	62	54	40	22	6	0						
APR 11-20								0	4	14	26	33	33	27	16	5	0							
APR 21-30									0	2	7	11	11	7	3	0								
MAY 1-10											0	1	1	0										
MAY 11-20																								
MAY 21-31																								
JUN 1-10																								
JUN 11-20																								
JUN 21-30																								
JUL 1-10																								
JUL 11-20																								
JUL 21-31																								
AUG 1-10										0	0	1	1	0	0									
AUG 11-20									0	1	5	10	10	6	2	0								
AUG 21-31								0	4	14	25	34	35	28	15	3	0							
SEP 1-10							0	6	20	38	53	64	66	58	43	23	6	0						
SEP 11-20						0	6	26	49	69	85	96	97	91	76	53	28	7	0					
SEP 21-30					0	6	26	56	82	103	122	133	135	129	114	85	56	26	5	0				
OCT 1-10				0	7	25	55	85	114	139	161	170	172	167	146	118	88	56	25	6	0			
OCT 11-20			1	7	26	53	88	122	152	184	209	226	225	212	189	157	124	91	55	28	9	1		
OCT 21-31	1	4	13	30	55	85	117	156	185	202	214	221	219	211	199	175	147	115	84	55	31	13	4	1
NOV 1-10	15	21	35	57	85	123	161	199	233	252	261	272	275	277	258	226	192	151	115	83	58	36	23	16
NOV 11-20	32	40	56	77	102	134	167	202	238	264	280	282	280	265	245	225	196	163	130	103	78	55	41	34
NOV 21-30	49	57	76	100	130	168	212	253	298	329	355	370	368	347	311	282	243	204	165	128	102	78	61	52
DEC 1-10	61	71	85	109	138	173	209	247	278	290	315	338	336	315	288	260	224	186	160	130	104	83	68	59
DEC 11-20	70	77	95	119	151	189	223	260	298	337	364	374	374	363	344	307	267	221	178	149	122	95	77	70
DEC 21-31	70	78	96	122	150	188	232	275	315	343	367	381	384	351	340	315	275	234	190	154	121	96	80	72

HALLEY BAY; HOURLY MEAN VALUES OF REFLECTED SOLAR RADIATION, R, IN W m.$^{-2}$

	MEAN HOURLY VALUES FOR THE HOUR BEGINNING AT L.A.T.																							
HOUR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
JAN 1-10	71	79	97	124	161	202	259	314	368	412	438	455	458	443	414	375	325	270	223	177	132	102	80	69
JAN 11-20	56	64	78	104	143	189	242	294	341	391	426	445	441	423	396	354	306	256	203	155	113	87	65	55
JAN 21-31	35	41	58	84	119	162	213	270	317	353	385	401	398	390	363	315	266	219	169	125	86	59	41	33
FEB 1-10	15	21	33	52	81	120	163	217	261	305	334	346	350	334	303	263	220	173	123	84	52	30	18	13
FEB 11-20	2	5	13	30	56	92	132	178	222	262	287	303	302	297	264	229	184	139	93	54	28	11	4	2
FEB 21-29			1	9	28	59	101	144	187	226	254	269	270	258	226	192	149	102	62	29	9	1		
MAR 1-10				1	10	35	71	113	155	194	219	233	234	216	190	151	108	68	32	9	1			
MAR 11-20					1	10	34	70	107	143	169	185	183	169	139	106	66	32	8	0				
MAR 21-31						0	8	29	56	83	105	120	121	105	83	56	28	7	0					
APR 1-10							0	7	24	46	63	75	72	61	44	24	6	0						
APR 11-20								0	5	17	29	37	36	29	17	5	0							
APR 21-30									0	2	8	13	13	8	2	0								
MAY 1-10											0	1	1	0										
MAY 11-20																								
MAY 21-31																								
JUN 1-10																								
JUN 11-20																								
JUN 21-30																								
JUL 1-10																								
JUL 11-20																								
JUL 21-31																								
AUG 1-10										0	0	1	1	0	0									
AUG 11-20									0	1	5	10	11	6	2	0								
AUG 21-31								0	4	15	28	37	38	29	15	3	0							
SEP 1-10							0	5	23	44	62	74	76	65	46	23	5	0						
SEP 11-20						0	7	29	58	88	113	126	126	114	90	57	26	6	0					
SEP 21-30					0	6	27	61	97	129	158	176	174	164	137	99	62	26	5	0				
OCT 1-10				0	7	27	63	106	145	183	208	223	224	213	183	146	105	62	27	6	0			
OCT 11-20			1	8	29	60	103	153	199	239	270	284	287	271	243	198	151	105	62	29	9	1		
OCT 21-31	1	4	13	31	64	106	157	213	264	311	344	363	367	351	315	269	217	162	110	67	34	14	4	1
NOV 1-10	14	21	35	59	94	139	188	248	301	345	381	402	399	381	347	298	252	195	140	94	60	36	22	16
NOV 11-20	36	45	65	94	132	183	236	292	340	391	429	446	446	427	394	353	298	241	189	141	97	65	46	36
NOV 21-30	54	62	82	111	149	199	256	316	371	412	443	459	458	446	410	365	313	263	208	156	117	87	67	57
DEC 1-10	75	84	104	139	184	231	285	343	401	445	475	491	493	476	449	403	352	299	241	186	144	110	87	76
DEC 11-20	80	88	110	140	180	225	282	337	389	435	465	489	485	469	435	391	339	283	232	185	143	109	90	80
DEC 21-31	75	83	104	134	172	217	277	333	381	424	457	472	471	458	429	387	335	282	231	183	140	109	87	76

HALLEY BAY; HOURLY MEAN VALUES OF NET RADIATION, Q, IN W m.$^{-2}$

HOUR	MEAN HOURLY VALUES FOR THE HOUR BEGINNING AT L.A.T.																							
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
JAN 1-10	-16	-14	-11	-6	4	13	24	36	47	58	61	65	64	59	50	42	29	16	6	-2	-10	-14	-17	-19
JAN 11-20	-19	-17	-13	-9	-1	8	19	31	41	52	58	64	62	57	49	38	27	14	4	-6	-13	-16	-19	-19
JAN 21-31	-21	-17	-15	-11	-4	4	14	27	38	47	54	56	53	49	39	27	17	7	-3	-10	-16	-19	-20	-21
FEB 1-10	-14	-14	-13	-12	-7	-1	6	16	24	32	36	40	39	35	28	20	11	2	-5	-10	-14	-15	-16	-16
FEB 11-20	-20	-19	-19	-19	-18	-11	-2	8	17	25	29	32	32	29	20	12	3	-5	-11	-16	-18	-18	-19	-18
FEB 21-29	-19	-18	-17	-16	-18	-17	-7	-1	6	13	18	18	19	17	10	6	-1	-9	-15	-19	-20	-21	-21	-23
MAR 1-10	-24	-23	-22	-22	-22	-28	-28	-18	-7	1	6	10	9	7	1	-6	-11	-17	-21	-22	-22	-23	-22	-21
MAR 11-20	-22	-20	-20	-19	-19	-18	-20	-19	-14	-8	-2	1	-0	-4	-10	-14	-18	-21	-22	-20	-20	-20	-20	-22
MAR 21-31	-16	-16	-17	-16	-16	-16	-16	-17	-16	-12	-9	-8	-8	-8	-10	-13	-16	-18	-19	-19	-19	-19	-17	-17
APR 1-10	-16	-15	-14	-14	-14	-15	-16	-17	-18	-18	-17	-14	-15	-16	-17	-18	-19	-17	-17	-17	-16	-14	-14	-12
APR 11-20	-18	-18	-17	-18	-17	-18	-19	-20	-18	-19	-20	-19	-20	-18	-18	-18	-17	-17	-17	-17	-17	-17	-19	-18
APR 21-30	-22	-22	-23	-24	-23	-22	-23	-24	-22	-22	-22	-21	-22	-22	-23	-23	-23	-23	-21	-21	-20	-22	-22	-22
MAY 1-10	-20	-20	-18	-19	-19	-21	-20	-20	-20	-20	-21	-19	-19	-19	-20	-19	-19	-18	-18	-19	-19	-19	-18	-18
MAY 11-20	-18	-19	-19	-21	-20	-19	-20	-20	-20	-20	-19	-19	-18	-19	-19	-19	-19	-20	-21	-21	-19	-19	-19	-17
MAY 21-31	-19	-18	-17	-18	-16	-16	-16	-17	-16	-18	-17	-16	-17	-18	-19	-19	-19	-20	-20	-19	-18	-19	-19	-21
JUN 1-10	-23	-21	-21	-22	-21	-21	-21	-20	-23	-23	-22	-22	-22	-22	-23	-21	-21	-21	-22	-22	-22	-22	-23	-24
JUN 11-20	-24	-25	-23	-23	-24	-23	-22	-23	-22	-23	-22	-22	-22	-22	-23	-23	-22	-22	-20	-22	-23	-24	-24	-24
JUN 21-30	-24	-25	-25	-25	-25	-24	-26	-25	-24	-24	-21	-19	-19	-19	-20	-21	-19	-18	-19	-19	-20	-21	-22	-23
JUL 1-10	-24	-23	-24	-25	-25	-26	-27	-27	-25	-25	-25	-24	-26	-26	-25	-25	-25	-25	-24	-26	-26	-25	-24	-25
JUL 11-20	-21	-22	-23	-22	-22	-21	-22	-22	-21	-20	-19	-21	-21	-21	-22	-23	-22	-21	-20	-21	-21	-21	-21	-20
JUL 21-31	-19	-20	-20	-20	-20	-20	-20	-20	-21	-21	-21	-22	-22	-21	-22	-23	-23	-23	-24	-23	-23	-23	-22	-22
AUG 1-10	-22	-23	-23	-23	-20	-21	-22	-23	-22	-20	-19	-19	-20	-19	-19	-20	-20	-21	-20	-19	-18	-20	-22	-23
AUG 11-20	-23	-23	-24	-22	-21	-22	-24	-24	-23	-22	-24	-25	-23	-24	-24	-24	-23	-24	-24	-23	-24	-23	-23	-23
AUG 21-31	-21	-20	-20	-19	-19	-20	-20	-21	-22	-21	-21	-20	-20	-20	-21	-21	-21	-20	-21	-20	-19	-19	-20	-21
SEP 1-10	-20	-20	-20	-17	-18	-18	-18	-18	-19	-19	-17	-17	-19	-20	-21	-20	-18	-18	-18	-19	-19	-22	-21	-20
SEP 11-20	-20	-20	-20	-20	-21	-21	-21	-24	-25	-24	-20	-19	-19	-20	-22	-24	-24	-21	-20	-21	-21	-21	-21	-20
SEP 21-30	-17	-16	-15	-15	-17	-17	-18	-17	-16	-10	-2	-2	-4	-9	-15	-20	-25	-24	-22	-18	-17	-18	-19	-17
OCT 1-10	-20	-21	-22	-22	-19	-21	-24	-19	-7	3	9	11	9	5	-4	-11	-19	-22	-23	-22	-21	-20	-21	-22
OCT 11-20	-18	-18	-18	-17	-19	-19	-13	-4	5	15	21	22	20	15	7	-2	-10	-16	-21	-23	-22	-23	-23	-22
OCT 21-31	-28	-28	-27	-28	-30	-21	-7	7	17	24	29	31	29	21	12	2	-7	-14	-22	-27	-29	-29	-29	-28
NOV 1-10	-22	-21	-18	-16	-12	-2	6	15	25	32	38	41	38	33	26	15	6	-5	-13	-18	-23	-23	-24	-24
NOV 11-20	-25	-23	-23	-19	-12	-2	10	21	31	40	48	50	48	41	32	22	10	-1	-10	-17	-22	-24	-26	-25
NOV 21-30	-16	-14	-12	-9	-3	7	20	31	42	51	57	61	59	54	43	33	20	11	1	-7	-13	-17	-18	-18
DEC 1-10	-21	-18	-14	-7	0	12	24	37	49	57	63	66	63	55	45	33	19	6	-3	-12	-19	-23	-24	-25
DEC 11-20	-15	-10	-4	0	7	17	27	38	47	56	60	64	59	54	44	33	22	11	2	-4	-9	-14	-16	-15
DEC 21-31	-14	-12	-5	1	7	16	28	41	51	60	67	70	67	60	53	43	30	19	7	-2	-8	-14	-16	-15

APPENDIX G

ARGENTINE ISLANDS; VALUES OF COS z AT THE HALF-HOURS, L.A.T.; UNITS: 0·01

	AT THE HALF-HOURS BETWEEN THE EXACT HOURS L.A.T.																							
	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	20–21	21–22	22–23	23–24
JAN 5	-3	-1	4	12	20	30	40	50	59	66	71	73	73	71	66	58	50	40	30	20	11	4	-1	-3
JAN 15	-6	-3	2	9	18	28	38	48	57	64	69	72	72	69	64	57	48	38	28	18	9	2	-3	-6
JAN 26	-10	-7	-2	5	14	24	35	45	53	61	66	69	69	66	61	53	44	34	24	14	5	-2	-7	-10
FEB 5	-15	-12	-7	1	10	20	30	41	50	57	62	65	65	62	57	50	40	30	20	10	0	-7	-12	-15
FEB 15	-20	-17	-12	-4	5	15	26	36	45	53	58	61	61	58	53	45	36	25	15	4	-5	-12	-18	-21
FEB 25	-26	-23	-18	-10	-1	9	20	31	40	47	53	56	56	53	47	40	30	20	9	-1	-11	-18	-24	-27
MAR 5	-32	-29	-24	-16	-6	4	15	25	35	42	48	51	51	48	42	35	25	15	4	-7	-16	-24	-30	-32
MAR 15	-38	-35	-30	-22	-13	-2	9	19	29	36	42	45	45	42	36	28	19	8	-3	-13	-23	-30	-36	-39
MAR 26	-45	-42	-37	-29	-20	-9	2	12	22	29	35	38	38	35	29	22	12	1	-9	-20	-30	-37	-43	-46
APR 5	-51	-48	-43	-35	-26	-15	-4	6	16	23	29	31	31	28	23	15	6	-5	-16	-26	-35	-43	-49	-51
APR 15	-56	-54	-48	-41	-31	-21	-10	0	9	17	22	25	25	22	17	9	-0	-10	-21	-32	-41	-49	-54	-57
APR 25	-61	-58	-53	-46	-36	-26	-16	-5	4	11	17	19	19	17	11	4	-5	-16	-26	-37	-46	-53	-59	-62
MAY 5	-65	-63	-57	-50	-41	-31	-20	-10	-1	6	11	14	14	11	6	-1	-10	-21	-31	-41	-50	-58	-63	-66
MAY 15	-69	-66	-61	-54	-45	-35	-24	-14	-5	2	7	10	10	7	2	-6	-14	-24	-35	-45	-54	-61	-66	-69
MAY 26	-71	-69	-64	-57	-48	-38	-28	-18	-9	-2	3	6	6	3	-2	-9	-18	-28	-38	-48	-57	-64	-69	-72
JUN 5	-73	-71	-66	-58	-50	-40	-30	-20	-11	-4	1	3	3	1	-4	-11	-20	-30	-40	-50	-58	-66	-71	-73
JUN 15	-74	-71	-66	-59	-51	-41	-31	-21	-13	-5	-0	2	2	-0	-5	-13	-21	-31	-41	-51	-59	-66	-72	-74
JUN 25	-74	-72	-67	-59	-51	-41	-31	-21	-13	-6	-1	2	2	-1	-6	-13	-21	-31	-41	-51	-59	-67	-72	-74
JUL 5	-73	-71	-66	-59	-50	-40	-30	-20	-12	-4	1	3	3	1	-4	-12	-20	-30	-40	-50	-59	-66	-71	-73
JUL 15	-72	-69	-64	-57	-48	-38	-28	-18	-10	-2	3	5	5	3	-2	-9	-18	-28	-38	-48	-57	-64	-69	-72
JUL 26	-69	-67	-62	-54	-45	-35	-25	-15	-6	1	6	9	9	6	1	-6	-15	-25	-35	-45	-54	-61	-66	-69
AUG 5	-66	-63	-58	-51	-42	-32	-21	-11	-2	5	11	13	13	11	6	-2	-11	-21	-31	-42	-51	-58	-63	-66
AUG 15	-62	-60	-54	-47	-38	-27	-17	-6	3	10	16	18	18	16	10	3	-6	-16	-27	-37	-46	-54	-59	-62
AUG 26	-57	-54	-49	-41	-32	-22	-11	-0	9	16	22	25	25	22	17	9	-0	-11	-21	-32	-41	-49	-54	-57
SEP 5	-52	-49	-44	-36	-27	-16	-5	5	15	22	28	31	31	28	23	15	6	-5	-16	-26	-36	-43	-49	-51
SEP 15	-46	-43	-38	-30	-21	-10	1	11	21	29	34	37	37	34	29	21	12	1	-10	-20	-30	-37	-43	-46
SEP 25	-40	-37	-32	-24	-15	-4	7	18	27	35	40	43	43	40	35	27	18	7	-4	-14	-24	-31	-37	-40
OCT 5	-34	-31	-26	-18	-8	2	13	24	33	41	46	49	49	46	41	33	24	13	3	-8	-17	-25	-30	-33
OCT 15	-28	-25	-19	-12	-2	8	19	29	39	47	52	55	55	52	47	39	30	19	9	-2	-11	-19	-24	-27
OCT 26	-21	-18	-13	-5	4	14	25	35	45	52	58	60	60	58	52	45	36	25	15	4	-5	-12	-18	-20
NOV 5	-15	-13	-7	0	9	19	30	40	49	57	62	65	65	62	57	49	40	30	20	10	0	-7	-12	-15
NOV 15	-11	-8	-3	5	14	24	34	44	53	60	66	68	68	66	61	53	44	34	24	14	5	-2	-7	-10
NOV 25	-7	-4	1	8	17	27	37	47	56	63	68	71	71	68	63	56	47	37	27	17	9	1	-4	-6
DEC 5	-4	-1	4	11	20	30	40	49	58	65	70	73	73	70	65	58	50	40	30	20	11	4	-1	-4
DEC 15	-2	0	5	12	21	31	41	51	59	66	71	74	74	71	66	59	51	41	31	21	13	5	0	-2
DEC 26	-2	1	6	13	21	31	41	51	59	66	72	74	74	72	66	59	51	41	31	21	13	5	0	-2

In compiling this table, no account has been taken of the effects of atmospheric refraction.

APPENDIX H

HALLEY BAY; VALUES OF COS z AT THE HALF-HOURS, L.A.T.; UNITS: 0·01

AT THE HALF-HOURS BETWEEN THE EXACT HOURS L.A.T.

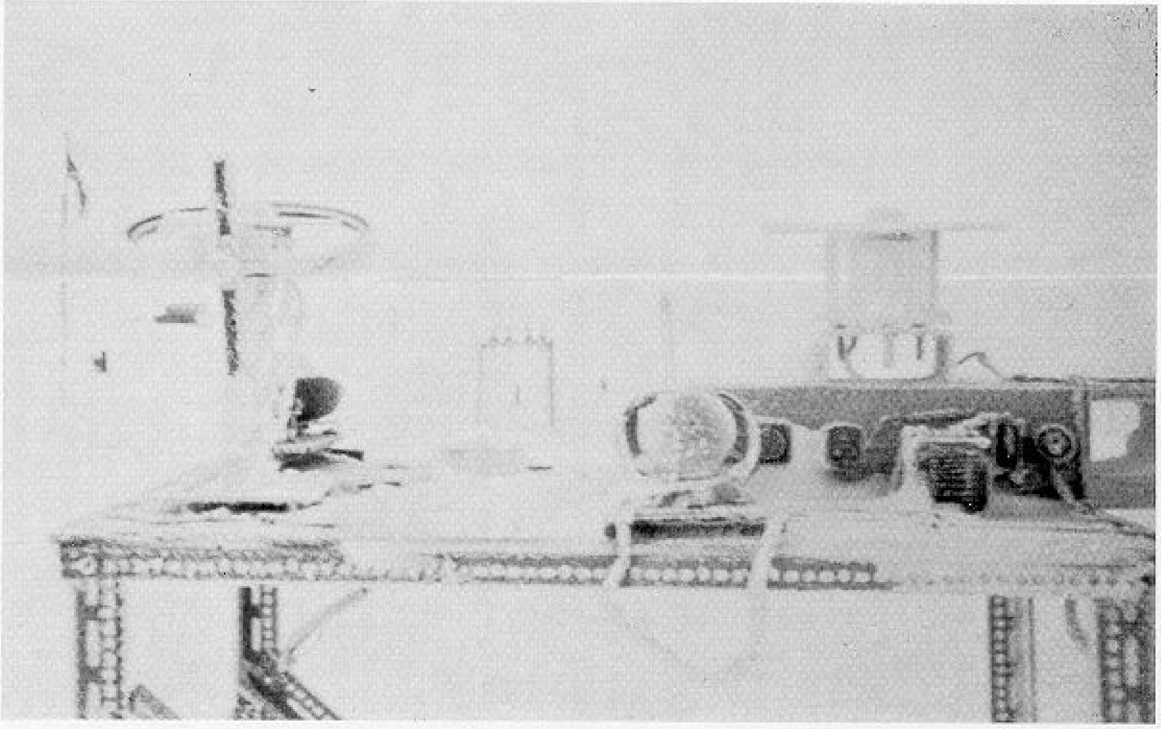
	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	20–21	21–22	22–23	23–24
JAN 5	15	16	19	23	29	34	40	46	51	56	59	60	60	59	56	51	46	40	34	28	23	19	16	14
JAN 15	12	14	17	21	26	32	38	44	49	54	57	58	58	57	54	49	44	38	32	26	21	16	13	12
JAN 26	8	10	13	17	22	28	34	40	46	50	53	55	55	53	50	46	40	34	28	22	17	12	9	8
FEB 5	3	5	8	12	18	24	30	36	42	46	49	51	51	49	46	41	36	30	24	17	12	8	4	3
FEB 15	-2	-1	2	7	12	19	25	31	36	41	44	46	46	44	41	36	31	25	18	12	7	2	-1	-3
FEB 25	-9	-7	-4	1	6	13	19	25	31	35	38	40	40	38	35	31	25	19	12	6	0	-4	-7	-9
MAR 5	-14	-13	-10	-5	1	7	13	20	25	30	33	35	35	33	30	25	19	13	7	0	-5	-10	-13	-15
MAR 15	-21	-19	-16	-12	-6	0	7	13	19	23	26	28	28	26	23	18	13	6	-0	-6	-12	-17	-20	-22
MAR 26	-28	-27	-24	-19	-13	-7	-1	6	11	16	19	21	21	19	16	11	5	-1	-7	-14	-19	-24	-27	-29
APR 5	-35	-33	-30	-25	-20	-14	-7	-1	5	9	13	14	14	12	9	5	-1	-7	-14	-20	-26	-30	-34	-35
APR 15	-41	-39	-36	-31	-26	-20	-13	-7	-2	3	6	8	8	6	3	-2	-7	-14	-20	-26	-32	-36	-40	-41
APR 25	-46	-45	-41	-37	-31	-25	-19	-13	-7	-3	0	2	2	0	-3	-8	-13	-19	-26	-32	-37	-42	-45	-47
MAY 5	-51	-49	-46	-42	-36	-30	-24	-18	-13	-8	-5	-3	-4	-5	-8	-13	-18	-24	-31	-37	-42	-47	-50	-51
MAY 15	-55	-53	-50	-46	-40	-34	-28	-22	-17	-13	-10	-8	-8	-10	-13	-17	-22	-28	-35	-41	-46	-50	-53	-55
MAY 26	-58	-56	-53	-49	-44	-38	-32	-26	-21	-16	-13	-12	-12	-13	-17	-21	-26	-32	-38	-44	-49	-54	-57	-58
JUN 5	-60	-58	-55	-51	-46	-40	-34	-28	-23	-19	-16	-14	-14	-16	-19	-23	-28	-34	-40	-46	-51	-56	-59	-60
JUN 15	-61	-60	-57	-52	-47	-41	-35	-30	-24	-20	-17	-16	-16	-17	-20	-24	-30	-35	-41	-47	-52	-57	-60	-61
JUN 25	-61	-60	-57	-52	-47	-41	-35	-30	-24	-20	-17	-16	-16	-17	-20	-24	-30	-35	-41	-47	-52	-57	-60	-61
JUL 5	-60	-59	-56	-52	-46	-40	-34	-29	-23	-19	-16	-15	-15	-16	-19	-23	-29	-34	-40	-46	-51	-56	-59	-60
JUL 15	-59	-57	-54	-50	-44	-39	-32	-27	-21	-17	-14	-12	-12	-14	-17	-21	-26	-32	-38	-44	-50	-54	-57	-58
JUL 26	-56	-54	-51	-47	-41	-35	-29	-23	-18	-13	-10	-9	-9	-10	-13	-18	-23	-29	-35	-41	-46	-51	-54	-55
AUG 5	-52	-50	-47	-43	-37	-31	-25	-19	-14	-9	-6	-4	-4	-6	-9	-13	-19	-25	-31	-37	-43	-47	-50	-52
AUG 15	-48	-46	-43	-38	-33	-27	-20	-14	-9	-4	-1	1	1	-1	-4	-8	-14	-20	-26	-32	-38	-42	-46	-47
AUG 26	-42	-40	-37	-32	-27	-21	-14	-8	-2	2	5	7	7	6	2	-2	-8	-14	-20	-27	-32	-37	-40	-41
SEP 5	-36	-34	-31	-27	-21	-15	-8	-2	4	8	12	13	13	12	9	4	-2	-8	-14	-21	-26	-31	-34	-36
SEP 15	-30	-28	-25	-20	-15	-8	-2	5	10	15	18	20	20	18	15	10	5	-1	-8	-14	-20	-24	-28	-29
SEP 25	-23	-22	-18	-14	-8	-2	5	11	17	21	25	26	27	25	22	17	11	5	-1	-8	-13	-18	-21	-23
OCT 5	-17	-15	-12	-7	-1	5	11	18	23	28	31	33	33	31	28	24	18	12	5	-1	-7	-11	-14	-16
OCT 15	-10	-9	-5	-1	5	11	18	24	30	34	37	39	39	37	34	30	24	18	12	5	-0	-5	-8	-10
OCT 26	-3	-2	1	6	12	18	24	30	36	40	44	45	45	44	41	36	31	24	18	12	6	2	-1	-3
NOV 5	2	4	7	12	17	23	29	35	41	45	49	50	50	49	46	41	36	30	23	17	12	7	4	3
NOV 15	7	9	12	16	22	28	34	40	45	50	53	54	54	53	50	45	40	34	28	22	17	12	9	8
NOV 25	11	13	16	20	25	31	37	43	49	53	56	58	58	56	53	49	43	38	31	26	20	16	13	11
DEC 5	14	15	19	23	28	34	40	46	51	55	58	60	60	58	55	51	46	40	34	28	23	19	16	14
DEC 15	15	17	20	24	29	35	41	47	52	57	60	61	61	60	57	52	47	41	35	30	24	20	17	16
DEC 26	16	17	20	24	30	35	41	47	52	57	60	61	61	60	57	52	47	41	35	30	24	20	17	16

In compiling this table, no account has been taken of the effects of atmospheric refraction.

PLATE I

a. Radiation platform at Halley Bay.

b. Hoar frost on total solarimeter at the Argentine Islands.

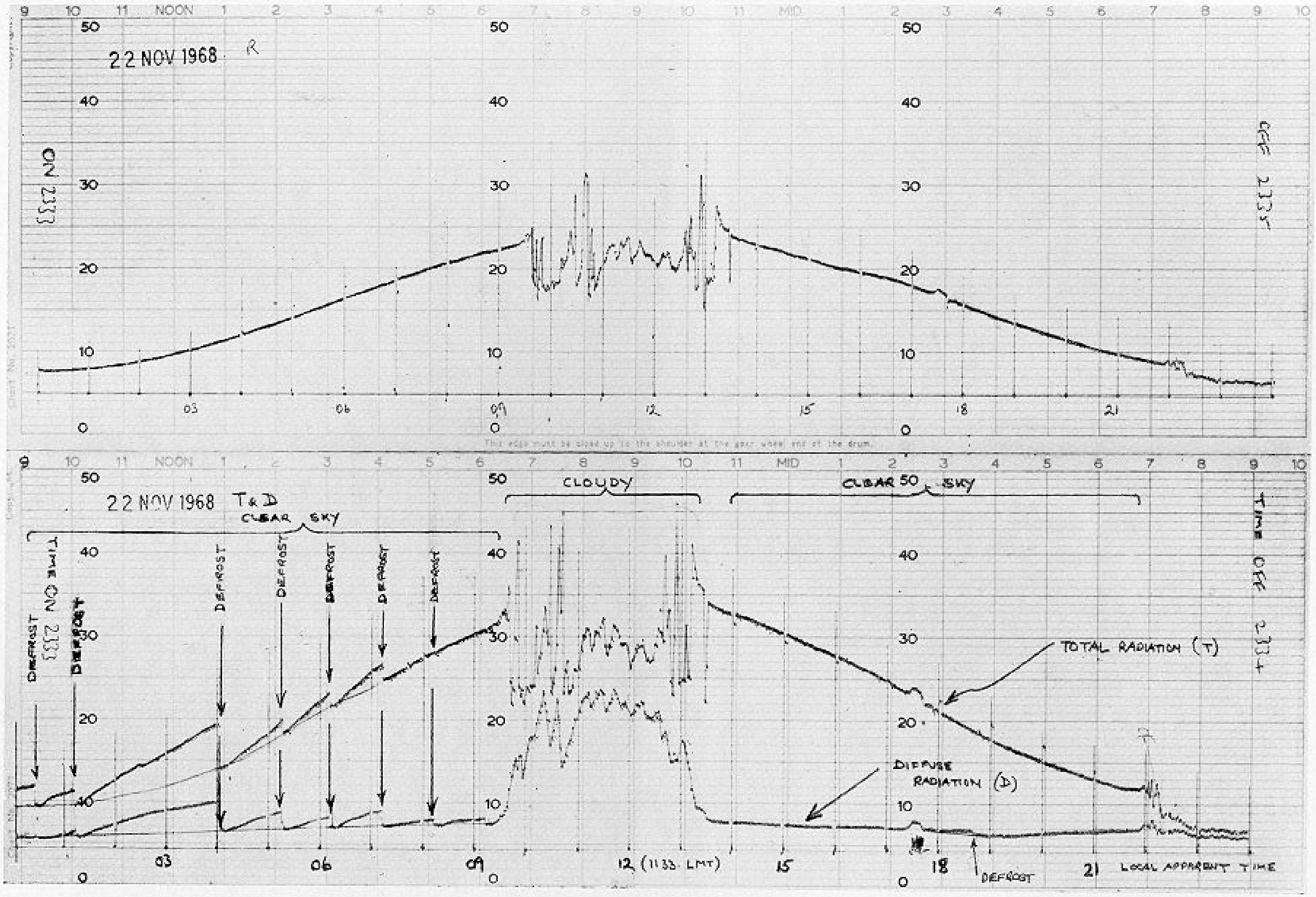


a

b

PLATE II

Original global, diffuse and reflected radiation records for Halley Bay, 22 November 1968. (Global radiation was formerly denoted "total" radiation).



22 NOV 1968 R
ON 2333
OFF 2335
22 NOV 1968 T&D
CLEAR SKY
TIME ON 2333
DEFROST
CLOUDY
CLEAR SKY
TIME OFF 2334
TOTAL RADIATION (T)
DIFFUSE RADIATION (D)
12 (1133 LMT)
DEFROST
LOCAL APPARENT TIME

PLATE II