Comments on the recent decrease in solar radiation at the South Pole

By HERBERT J. VIEBROCK and EDWIN C. FLOWERS, *Polar Meteorology Group, Environmental Science Services Administration, U.S. Department of Commerce*

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ABSTRACT

A study has been made of the decrease in intensity of the direct solar radiation at the South Pole which occurred in late 1963. The decrease has been ascribed to an influx of volcanic dust in the stratosphere from the eruption of Mt. Agung, Bali. Following the decrease in 1963, the direct solar radiation values gradually approached their normal value by February 1966. Measurements of the total solar radiation received at the surface show a much smaller decrease. The solar radiation budget during this period is discussed and the influence of the dust on the radiation examined. Air trajectories at several stratospheric levels were used to indicate the height of the influx over the South Pole and the probable source region of the aerosol outside the Antarctic continental limits.

1. Introduction

Beginning in 1957, solar radiation measurements have been made at the Amundsen-Scott (South Pole) Station as part of a comprehensive surface radiation program. With the exception of the period from January 1963 to October 1963, when the instruments were returned to the United States for calibration and other checks, the program has been in continuous operation. The solar portion of the radiation budget was obtained by measuring the normal-incident (direct component), horizontal-incident (total solar radiation), diffuse, and reflected radiation. In addition, some filter measurements were obtained of the direct solar beam. A photograph of the radiation instrumentation at the South Pole is shown in Fig. 1.

In November and December 1963 a series of sharp oscillations in intensity of the direct solar radiation occurred, followed by a marked decrease at the South Pole. There was a similar though considerably smaller decrease in the total solar radiation measured on a horizontal surface. These effects are believed to be due to an influx of volcanic dust at stratospheric levels from the eruption of Mt. Agung, Bali, in March 1963. Fig. 2. shows a map of the Southern Hemisphere indicating the location of Mt. Agung and the Antarctic continent. Only a few of the Antarctic stations have been labelled for reference purposes.

2. Direct solar radiation measurements

Direct solar radiation measurements were made with an automatic tracking Eppley Pyrheliometer with an aperture of 5°43′ and equipped with a collar containing three Schott filters. Pyrheliometer #3546 was used from 1959–66. Information on the calibration and data reduction techniques for this instrument is given by Flowers & Helfert (1965). A description of methods used to confirm the low values observed is given in Flowers & Viebrock (1965).

Fig. 3 shows the daily maximum direct solar radiation values measured from November 12, 1963, to February 16, 1966. The smooth upper curve shows the 1957–62 mean values with a mean deviation of $\pm 1.9\%$ which were assumed to represent the normal daily values.

The radiation instrumentation was removed on January 1, 1963, and returned in November 1963. Sharp oscillations were first noted in the

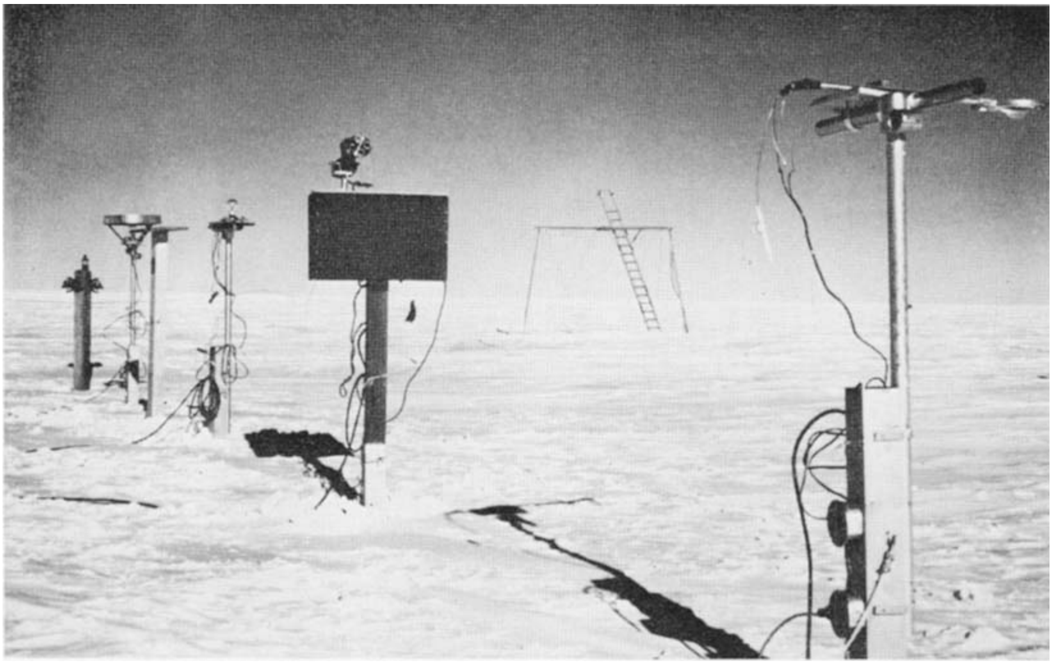

Fig. 1. The South Pole radiation instrumentation. From left to right: Campbell Stokes sunshine recorders, Eppley pyranometer with shade ring, empty platform, upfacing Eppley pyranometer, Eppley pyrheliometer with filter collar, downfacing Eppley pyranometer, and CSIRO (Funk) radiometer.

normal-incidence intensity curve in late November 1963. It appears that the observed intensity began to drop sharply in the latter part of November and early December from 96.3% of normal on November 12 to 72.3% on December 18. After December 18 the intensity continued to decrease slowly until sunset on March 21, 1964.

On the basis of this data, it appears that the atmospheric aerosol causing the reduction in the normal-incidence intensity arrived in massive amounts in late November and early December with only small continuous changes thereafter. Part of the decrease near sunset is due to the small solar elevation angle. The low radiation values near sunrise and sunset of the following two years show a similar effect. Clouds of the material seem to have passed over the station in October, November and early December of each of the austral summers.

The material seems to have spread relatively evenly throughout the Antarctic region following the large input in the austral summer of 1963–64. From October to February of the following two years the normal-incidence values are relatively uniform, ranging from 70–79% of normal in 1964–65 and from 90–95% of normal in 1965–66. A gradual return to normal is evident during this three year period and

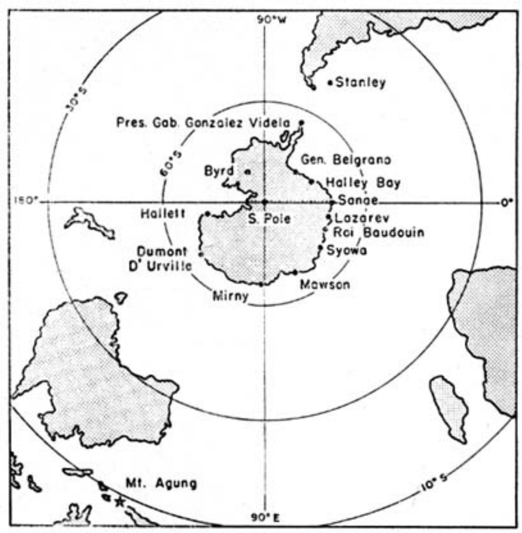

Fig. 2. Map of the Southern Hemisphere with the location of Mt. Agung marked by a star.

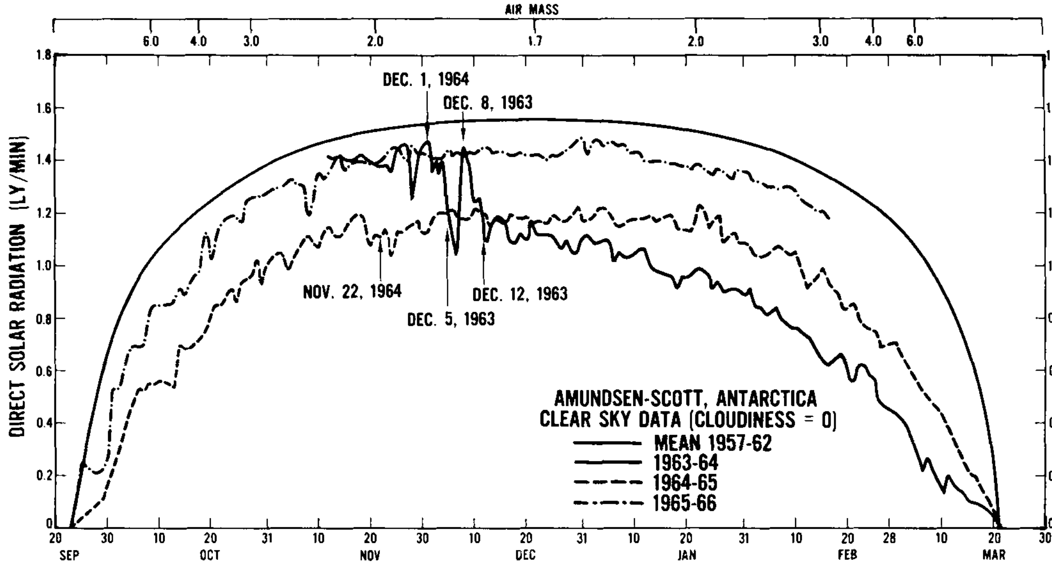

Fig. 3. Direct solar radiation data for Amundsen-Scott (South Pole) station.

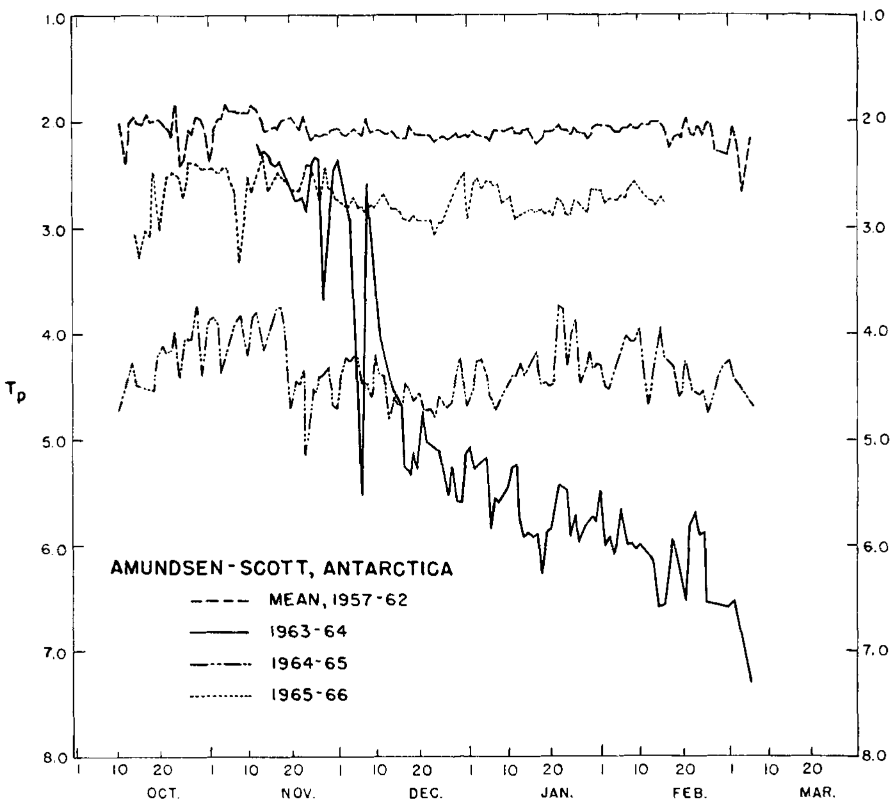

Fig. 4. Extrapolated turbidity factor, T_p, for Amundsen-Scott (South Pole) Station. T_p increases downward.

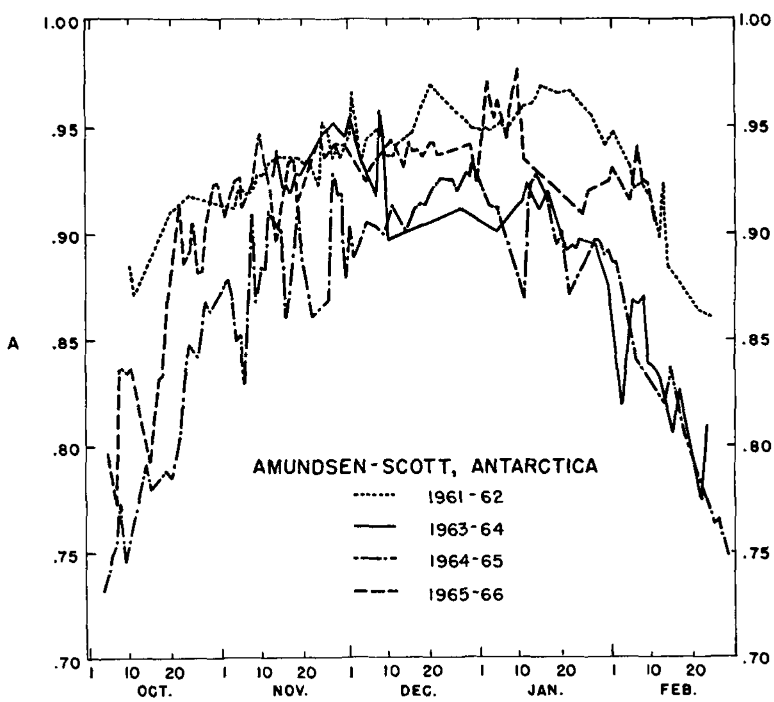

Fig. 5. Ratio, A, at Amundsen-Scott (South Pole) Station of the observed total solar radiation on a horizontal surface for clear skies to the theoretical values for a Rayleigh Atmosphere determined by Deirmendjian & Sekara (1954).

indicates the attrition of the aerosol through sedimentation and horizontal transfer.

The comments made above are very clearly illustrated in Fig. 4. Fig. 4 is a plot of the daily "extrapolated turbidity factor", T_p (Feusener & Dubois, 1930), computed from the normal-incidence values presented in Fig. 3. T_p is Linke's turbidity factor extrapolated to sea level. For the 1957–62 base period, the average daily values were used rather than the smoothed values. The values for this period centered around 2.1 as shown by the upper curve. A sharp increase in the turbidity values occurred in late November 1963 and continued to increase until March 1964.

From October to February of the following years the turbidity factors are relatively uniform ranging from 3.7 to 5.2 in 1964–65 and from 2.4 to 3.3 in 1965–66. Gradually as the atmospheric aerosol was depleted the turbidity value tended to approach the 1957–62 values.

3. Total solar radiation measurements

Using Eppley 50-junction pyranometer #3070, total (horizontal-incidence) solar radiation measurements were made over the same period as the normal incidence observations. Calibration and data reduction corrections are discussed in Flowers & Helfert (1965). This data was compared with theoretical values derived by Deirmendjian & Sekera (1954), for radiation reaching the surface through a Rayleigh atmosphere with multiple scattering.

A graph of the ratio, A, of the observed values to the theoretical values is presented in Fig. 5 for the years from 1961 to 1966. The ratio, A, was determined for days with clear skies at 1200 GMT. Deirmendjian & Sekera estimated the radiation on a horizontal surface for several values of the surface albedo. Their values for an albedo of .80 were used. The ratio, A, is a measure of the attenuation of the solar radiation due to absorption by ozone, water vapor and aerosols, and scattering by aerosols. Therefore a decrease in A means an increase in attenuation due to absorption and non-Rayleigh scattering.

The period from 1961 to 1962 was used to provide a base for comparative purposes. Values during this period ranged from .89–.97

from November to February. Similar values occur in early November 1963. In late November and early December 1963 the ratio dropped to .89–.92 and remained there until early February when it began to drop continuously until sunset. This latter effect near sunset and sunrise occurs in all the years and is a function of the low solar elevation angle.

By the following austral summer the values of A ran from .78 to .93. The greatest fluctuation occurred during October, November and early December 1964. In the 1965–66 austral summer the total solar radiation values have become almost indistinguishable from those of the base year. Strong oscillations occurred again during the spring of 1965.

There are two possible explanations for the fluctuations which occurred during the spring of 1964. Since these oscillations seem to occur at or near the time of the spring stratospheric warmings, they may be due to the passage of clouds of the atmospheric aerosol over the station. During 1964 and 1965, the ozone absorption accounted for only part of the amplitude of the oscillation. It played a greater role in 1965 than in 1964. Therefore, it seems likely that clouds of material passed over the station each spring. Following the oscillations the observed values assume a fairly uniform value which is higher than that for the previous year indicating an apparently uniform distribution of the material but of lower density.

It appears, as is also clearly shown by the direct solar radiation data previously discussed, that most of the aerosol causing the observed reduction over the three year period had been removed from the atmosphere over the South Pole by 1966.

Simultaneously with the total and normal-incidence observations, measurements of the diffuse radiation reaching the surface were made using a shielded Eppley pyranometer. Even though the total radiation has virtually returned to normal by 1966 the ratio of the diffuse to the total is still slightly higher. This is shown in Table 1 for selected clear days between February 10 and 15 for five years: two prior to and three after the arrival of the aerosol. The ratio is .185 and .210 in 1960 and 1962 respectively. This is the result of Rayleigh scattering and scattering by the normal aerosol content of the Antarctic atmosphere. Following the arrival of the dust in late 1963, the ratio increased to a value of .533 in 1964. This was followed by a gradual decrease in the ratio to .375 in 1965 and .257 in 1966, reflecting the gradual depletion of the dust.

Table 1. *Variation of the diffuse to total solar radiation ratio for selected days from February 10–15*

Year	Normal-incidence	Diffuse	Total	Diffuse/total
1960	.349	.079	.428	.185
1962	.345	.092	.437	.210
1964	.189	.216	.405	.533
1965	.263	.158	.421	.375
1966	.329	.114	.443	.257

It should be noted that there was only a small decrease in the total values. The small decrease in the total solar radiation accompanying a large decrease in the direct beam was also observed by Bosua (1963) and Dyer & Hicks (1965). Similar effects were found as a result of the Katmai eruption in 1912 (Kimball, 1914).

4. Aerosol source and height

Reduction in solar radiation and increases in atmospheric turbidity were reported from many points of the globe beginning in the late spring of 1963 (Bosua, 1963; Hogg, 1963; Burdecki, 1964; Moreno & Stack, 1964; Volz, 1965; Flowers & Viebrock, 1965). Simultaneously, many observers (Hogg, 1963; Burdecki, 1963; Meinel & Meinel, 1963, 1964; Volz, 1964), reported brilliant atmospheric optical phenomena beginning approximately at the same time. All of these effects have been ascribed to the eruption of Mt. Agung, Bali (8°25′ S, 115°30′ E) on 17 March 1963.

Earlier eruptions, such as Krakatoa in 1883 and Katmai in 1912, produced similar effects. These have been discussed by various authors for different volcanic eruptions including Symons (1888) (Krakatoa), Wexler (1951), (Krakatoa), Humphreys (1913, 1940) (Katmai) Kimball (1912, 1913*a*, 1913*b*, 1914, 1918) (Katmai), and Rimmer (1937) (Andes in 1932).

Estimates of the height of the aerosol from the Mt. Agung eruption were made by several authors using various optical techniques. Meinel & Meinel (1963) using the twilight glow estimated the dust layer to be at 22.3 km over

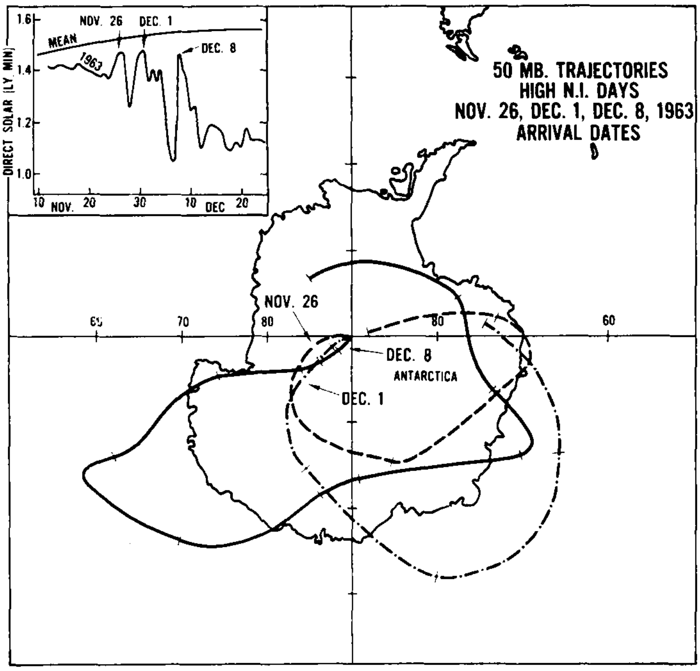

Fig. 6. 50 mb trajectories for air arriving at the South Pole on November 26, December 1 and December 8, 1963. The diagram in the upper left shows the direct solar radiation values at the South Pole on these dates.

Tucson, Arizona, in September 1963. In 1964, they obtained a corrected mean height of the layer at 17.8 km and the top at 20 km based on observations in November 1963. Volz (1964) obtained values of 20–25 km over Weissenau in November 1963 using similar techniques. In 1965 he estimated the dust in May of 1963 to be at about 17 km or 100 mb over Weissenau. Harris (1964) using the extinction of sunlight reflected from a balloon computed heights of 21–25 km in October 1963 and 19–23 km in May 1964 over Melbourne, Australia.

Mossop (1964) detected volcanic particles in samples collected by U-2 aircraft flying at 20 km along 145° E from 15–35° S and 40–45° S during 1963 and 1964. Rosen (1964) made a number of balloon soundings of the atmospheric aerosol content over Minnesota using a photoelectric particle counter. His soundings show a large flat maximum at 80 to 150 mb. The author makes no attempt to identify the source, but the large values found in this layer during 1963 and 1964 could be related to the influx of volcanic debris. Several trajectories were drawn at 100 mb using monthly mean charts to examine the possibility that the dust observed by Rosen might have come from low latitudes. The air parcels can be easily traced to low latitudes, so that an equatorial source for the material is possible.

Based on the various estimates mentioned above, daily trajectories were drawn for the Antarctic region on the 30 (22–24 km), 50 (19–20 km), 100 (15–16 km), and 200 mb (10–11 km) surfaces for the months of November and December 1963. It was hoped that the trajectory analysis would provide some clue as to the level or layer where the dust was located and the direction of the influx from the surrounding oceanic regions. Dyer & Hicks (1965), assumed a height of 10 km over the South Pole in their analysis. The actual force of the eruption, height of injection of the debris and quantity of material injected are unknown.

Geostrophic trajectories were drawn back in time beginning on each day from November 15 to December 31, 1963 at the South Pole. Figs. 6–7 show the trajectories from 6 selected days on the 50 mb surface. The diagram in the upper left hand corner of the figures shows the South

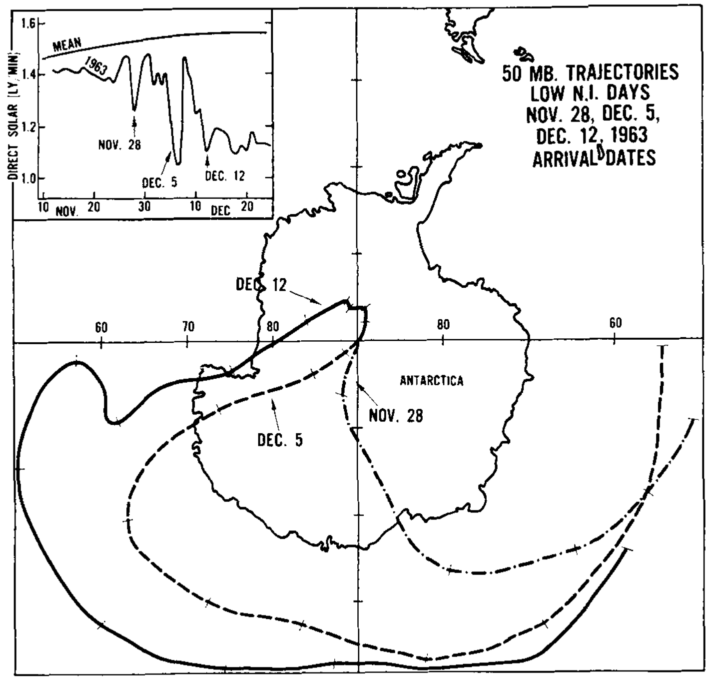

Fig. 7. Similar to Fig. 6, but for November 28, December 5 and December 12, 1963.

Pole normal-incidence curve for November and December 1963. For illustrative purposes, three cases when the observed direct solar radiation values were low and three when they were high were selected for presentation. November 26, December 1, and December 8 were chosen as days when the atmospheric attentuation of the direct solar beam was small. November 28, December 5, and December 12 represent days when the attenuation was high.

The trajectories can be divided into two groups on the basis of the origin of the air parcels in the Antarctic region: continental and oceanic. Termination of the trajectories was based on three criteria: the trajectory passed out of the Antarctic region; it entered a region where the data was insufficient for analysis; or a firm pattern had been formed after a minimum of ten days. In the figures the trajectories have been drawn only as far as necessary to indicate the pattern and to avoid overlapping of the lines.

The 30 mb trajectories indicated oceanic origins on December 5, 8 and 12 and continental origins on November 26 and 28 and December 1. At 50 mb (Figs. 6–7) November 28, December 5 and December 12 are oceanic, while November 26, December 1 and December 8 are continental.

Table 2. *Normal-incidence values vs trajectory origin*

Date	N.I.	30 mb	50 mb	100 mb	200 mb
26 Nov.	High	Cont.	Cont.	Cont.	Cont.
28 Nov.	Low	Cont.	Oceanic	Cont.	Cont.
1 Dec.	High	Cont.	Cont.	(?)	Cont.
5 Dec.	Low	Oceanic	Oceanic	Cont.	Cont.
8 Dec.	High	Oceanic	Cont.	Cont.	Cont.
12 Dec.	Low	Oceanic	Oceanic	Cont.	Cont.

Table 3. *Attenuation of the normal solar beam*

All radiation values are in ly/min

Date	Elev. angle	Air mass	ETR	Normal incident	Total attenuation	Attenuation due to O_3	H_2O	Rayleigh	Aerosol
14 Jan. 1962	21°20′	1.86	2.068	1.555	.513	.067	.031	.222	.193
12 Jan. 1964	21°45′	1.82	2.068	1.014	1.054	.067	0.31	.218	.738
10 Feb. 1962	14°25′	2.70	2.054	1.385	.669	.083	.034	.280	.272
10 Feb. 1964	14°34′	2.70	2.054	.784	1.270	.078	.034	.274	.884
9 Feb. 1965	14°39′	2.60	2.054	1.023	1.031	.081	.034	.275	.641
9 Feb. 1966	14°44′	2.60	2.054	1.287	.767	.081	.034	.273	.379

On the 100 and 200 mb. surfaces all the trajectories are continental. Table 2 compares the trajectory origins with the normal-incident (direct) solar radiation values.

The correlation between the normal-incidence (N.I.) values and the 50 mb level appears to be good; with low N.I. values resulting from clouds of dust brought in from the oceanic area north of the continent. This appears to agree with the assumption that the source of the stratospheric dust was north of the continent, probably Mt. Agung. The major portion of the material arrived 8–9 months after the eruption.

Another possibility is a continental source, but no visual or seismic indications of an eruption have been reported from any of the continental stations. Even with the relatively sparse network of stations, an eruption of sufficient force to place material in the stratosphere would have been easily detectable on a seismograph.

On the basis of the analysis shown in Table 2 and the indications of a source outside the Antarctic Continent, the dust apparently reached the South Pole at or near the 50 mb level. It must lie between 16 (100 mb) and 22 (30 mb) km, a relatively narrow layer. This is in substantial agreement with the findings of Harris (1964), who estimated the height to be between 21–25 km in October 1963 over Melbourne, Australia.

5. Solar radiation budget

The measured surface solar radiation fluxes for selected days in pre-dust and dust years are presented in Tables 3 and 4 along with estimate of the atmospheric attenuation of the incoming radiation. Two periods were selected for comparison between dust and pre-dust years: one when the sun is near it highest elevation in January and one when the sun is lower in the sky in February. At the South Pole the sun shines twenty-four hours a day for approximately a six month period, with very little variation in elevation during the day. The selected days are cloudless.

Table 3 shows the attenuation of the direct beam. During January the solar elevation is about 21–1/2° with an air mass of 1.82 to 1.86 and an extra-terrestrial radiation (ETR) value of 2.068 ly/min; while in February the solar elevation is about 14–1/2° with an air mass of 2.60 to 2.70 and ETR of 2.054 ly/min. The extra-terrestrial radiation values are based on a solar constant of 2.00 ly/min. Corrections have been applied to the normal-incident values for the effect of the solar aureole (Ångström, 1964*a*, 1964*b*, Ångström & Rodhe, 1966). The total attenuation is simply the difference between the ETR and the normal-incident value.

Ozone absorption was computed first using the Vigroux absorption coefficients and assuming that all the ozone was located in a layer at the top of the atmosphere. Actual observations

Table 4. *Horizontal-incident solar radiation*

All values in ly/min

Date	Direct	Diffuse	Total	Reflected	Albedo
14 Jan. 1962	.566	.106	.672	.545	.81
12 Jan. 1964	.376	.280	.656	.541	.82
10 Feb. 1962	.345	.092	.437	.372	.85
10 Feb. 1964	.197	.208	.405	.336	.83
9 Feb. 1965	.259	.162	.421	.349	.83
9 Feb. 1966	.327	.116	.443	.363	.82

Table 5. *Diffuse radiation*

All radiation values in ly/min

Date (1)	Rayleigh atten. of direct (2)	Aerosol atten. of direct (3)	Total atten. of direct (4)	Rayleigh downward 0 alb. (5)	Rayleigh downward .80 alb. (6)	Albedo effect (6)–(5) (7)	Diffuse (8)	Diffuse – alb. effect (8)–(7) (9)	Diffuse (–) total atten. (9)/(4) (10)	–Aerosol cont. to diffuse (8)–(6) (11)	Aerosol cont. dust atten. (11)/(3) (12)
14 Jan. 62	.080	.070	.150	.040	.063	.023	.106	.083	.553	.043	.614
12 Jan. 64	.080	.273	.353	.040	.063	.023	.280	.257	.728	.217	.794
10 Feb. 62	.069	.068	.137	.034	.049	.015	.092	.077	.562	.043	.632
10 Feb. 64	.069	.222	.291	.034	.048	.014	.208	.194	.666	.160	.720
9 Feb. 65	.069	.162	.231	.034	.049	.015	.162	.147	.636	.113	.697
9 Feb. 66	.069	.096	.165	.034	.049	.015	.116	.101	.612	.067	.697

of the total ozone made at the South Pole were used. The spectral distribution of the extraterrestrial solar radiation used came from Johnson (1954). Attenuation due to Rayleigh scattering was found next by utilizing the relative diffuse sky radiation from Deirmendjian & Sekera (1954) for 0 albedo and assuming that the downward scattered radiation was 50% of the Rayleigh scattering attenuation. Water vapor absorption was determined by using the curves presented by Kimball (1928). All calculations were based on actual observed vertical distributions of temperature and moisture. Above the −40°C level saturation was assumed. This results in a slight overestimate of the effect of water vapor. The effect of absorption and scattering by the atmospheric aerosol content was obtained as the residual.

There is very little change during a given period between the pre-dust and dust years in the absorption by ozone and water vapor and the attenuation due to Rayleigh scattering. In January the effect of aerosol absorption and scattering increased by a factor of 3.8 from pre-dust to dust year. Similarly in February it increased by 3.75. Gradually it is returning to the pre-dust value reached in February, 1962. In February 1965 it is only 2.36 times greater, while in 1966 it is greater by only 1.39. This reflects the gradual attrition of the dust with time.

Table 4 shows the variation of the solar radiation values measured on a horizontal surface. The total horizontal-incident solar radiation varies little between dust and non-dust years. In January it decreased in 1964 to 97.6% of the 1962 value, while in February it decreased to 93% of the 1962 value. By 1965 it had returned to 97% of the 1962 value and in 1966 it was equivalent to that of 1962.

Even though the direct component shows a large decrease, this is almost completely compensated by an increase in the amount of diffuse radiation. This implies that the aerosol causing the increased attenuation of the direct beam is primarily a scatterer rather than an absorber. The albedo has remained virtually unchanged during this time, so that the amount of radiation reflected and absorbed by the snow varied directly with the incoming total solar radiation.

A breakdown of the diffuse radiation reaching the surface is outlined in Table 5. Columns 2 through 4 indicate the attenuation of the direct beam by Rayleigh and aerosol scattering and aerosol absorption. The values listed in these columns come from Table 3 with the appropriate geometric corrections to reduce them to components on a horizontal surface.

Columns 5 through 7 outline the effect of the high surface albedo on the Rayleigh scattering. The downward Rayleigh scattered diffuse radiation was determined by using the relative diffuse values in Table 2 from Deirmendjian & Sekera (1954). As done previously the spectral breakdown of solar radiation from Johnson (1954) was used here. Deirmendjian & Sekera's computations included the effects of multiple-scattering and albedo. Column 7 represents the difference between the multiple-scattering in a Rayleigh atmosphere when the surface albedo is 0 and .80. The effect of ozone absorption was removed before the Rayleigh scattering was determined. As is apparent from the table the high surface albedo of .80 contributes approximately one-third of the Rayleigh contribution to the diffuse radiation.

Column 8 lists the diffuse component of the total horizontal-incident solar radiation from Table 4. Column 9 is the same as column 8 minus the albedo effect. The ratio of the diffuse minus the albedo effect to the total attenuation of the direct beam due to scattering and aerosol absorption is shown in column 10. The ratio has increased from a normal to a dust year in both January to February, implying that there has been an increase in forward scattering. This is as might be expected, if there is an increase in large particles.

By subtracting column 6, the Rayleigh contribution, from column 8, the diffuse radiation, we obtain the aerosol contribution to the diffuse. This is listed in column 11. Column 12 indicates the percentage of the aerosol attenuation of the direct beam (column 3) that reaches the surface (column 11). The aerosol attenuation given here includes both scattering and absorption. From 1962 to 1964 in both January and February, the percentage increased, implying a greater increase in forward scattering than in absorption or back scatter. In the following year the forward scattering appears to have decreased. This may be due to the change in one of three particle characteristics or, as is more likely, a combination of them: (1) size, (2) configuration, and/or (3) composition (Absorptivity).

Mossop (1963, 1964, 1965), collected dust particles at 20 km over northern and southern Australia from an aircraft in 1963 and 1964. Prior to the incursion of volcanic dust, typical particles consisted of water-soluble material of about 1 μ in diameter containing insoluble nuclei about one-tenth of their diameter. Immediately following the eruption large angular particles covered by soluble material appeared. By December 1963 the particle size had diminished and the number of small volcanic particles had increased. All had a coating of soluble material. Additionally, prior to the eruption, the coating on the particles consisted of ammonium sulphate and persulphate. After the arrival of the volcanic material the amount of coating material increased and appeared to consist of sulphuric acid.

There appeared to be a decrease in particle size and an increase in the amount of fluid coating on the particles with time. Both of these changes would explain the decrease in forward scattering observed.

Conclusions

The sequence of events, based on the data presented here, seems to have been as follows:

1. On 17 March 1963, Mt. Agung, Bali, erupted violently, sending large quantities of volcanic material into the stratosphere. The force of eruption, amount of material injected into the atmosphere and height of the injection are unknown.

2. The material gradually spread over the Southern Hemisphere reaching South Africa in April (Bosua, 1963), Australia in April (Dyer and Hicks, 1965; Hogg, 1963), Chile in May (Moreno and Stock, 1964), and the South Pole in November (Flowers and Viebrock, 1965), 8 months after the eruption.

3. A large amount of dust did not enter the region occupied by the circumpolar vortex until it had weakened considerably in November. At that time the aerosol entered initially in the form of impulses or clouds. By the middle of December the dust had spread evenly throughout the region. Prior to the massive input in November and December, which was due almost entirely to advective processes, some dust had penetrated into the region by diffusion processes.

4. The dust, which was at a height of 21–25 km over Australia (Harris, 1964), is located in a relatively thin layer around the 50 mb surface. It is located between 16 and 22 km over the South Pole, probably closer to 19–20 km.

5. Most of the dust appears to have entered the continental area south of New Zealand and Australia in the sector from Hallett to Mawson.

6. The relatively constant aerosol density indicated by the solar radiation curves shown in Figs. 4 and 5 during the southern daylight or summer period each year suggests the depletion of the aerosol over the Antarctic occurs largely during the winter or dark period. This question remains to be explored.

7. Following the arrival of volcanic dust over the Antarctic continent in 1963, the normal-incident (direct) solar radiation values fell sharply at the South Pole, but the total solar radiation reaching the surface changed only slightly. The loss from the direct beam was

almost completely compensated for by the diffuse radiation. This indicates that the particles were primarily scatterers rather than absorbers.

8. With time there was a change in particle number and character. The change in number has resulted in the direct solar radiation values tending to return to their pre-dust values. A change in particle composition and mean size is indicated by a reduction in the amount of forward scatter.

Additional investigations are now underway to further examine the effect of volcanic material on the observed radiation by utilizing the pyrheliometric filter measurements; to examine the effect, if any, on the net radiometer measurements; to use the volcanic dust as a tracer in the study of the Southern Hemispheric circulation with special emphasis on the breakdown of the stratospheric circumpolar vortex; and to study other meteorological parameters to find the effect, if any, of the presence of volcanic dust.

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КОМЕНТАРИИ К НЕДАВНЕМУ УМЕНЬШЕНИЮ СОЛНЕЧНОЙ РАДИАЦИИ НА ЮЖНОМ ПОЛЮСЕ

Проведено изучение уменьшения интенсивности прямой солнечной радиации на Южном полюсе, имевшее место в конце 1963 года. Это уменьшение было приписано влиянию вулканической пыли в стратосфере от извержения вулкана Агунг на о. Бали. После уменьшения в 1963 г. интенсивность прямой солнечной радиации постепенно приближалась к своей нормальной величине, достигнутой в феврале 1966 г. Измерения полной солнечной радиации, приходящей к поверхности, указывают на гораздо более слабое уменьшение интенсивности. Обсуждается баланс солнечной радиации для этого периода и рассматривается влияние пыли на радиацию. Для установления высоты притока пыли к Южному полюсу были использованы траектории воздушных частиц на различных уровнях в стратосфере, послужившие также для определения возможной области происхождения аэрозоля вне антарктического континента.