STRATOSPHERIC TEMPERATURES OVER AUSTRALIA

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Summary

A study of the stratospheric temperatures over Australia has revealed apparent anomalously high temperatures during 1963–64. Although a change in the radiosonde type was made near the beginning of this period, it is unlikely that this change can have introduced a discontinuity of the magnitude observed. It is tentatively proposed that the anomaly may be related either to the effects of the Bali volcanic debris which appeared over Australia during the same period or to a change in the nature of the biennial oscillation.

I. Introduction

In a previous paper (Sparrow and Unthank 1964), a preliminary examination of the biennial temperature oscillation over Australia was reported. The Laverton and Hobart data at 60 and 50 mb had been shown to exhibit the quasi-biennial cycle reported by Reed (1960). However, this oscillation appeared to break down towards the end of 1962. It was then suggested that this may have been due to a temperature discontinuity arising from the introduction of the external-thermistor radiosonde at about this time. Further investigation has shown, however, that, although these sondes were introduced at about this time, many stations were carrying large stocks of the ducted-thermistor sondes, so that the change took place at different times at the different stations. It therefore seems likely that the change is an actual change of stratospheric temperature, and tentative suggestions are made as to the possible cause of this change. The occurrence of the temperature change at about the time of the Bali volcanic eruption is noted. An alternative mechanism relates to a breakdown in the biennial cycle during the same period.

II. Australian and New Zealand Temperatures

Table 1 shows the latitude and longitude of the Australian stations and the approximate times of introduction of the external thermistor sondes, as well as the same data for several New Zealand stations used in this analysis. Figures 1 and 2 show the monthly mean "2300 Z"† (daytime) temperatures for Darwin and Port Hedland, respectively, at 100, 60, and 50 mb; at Darwin, although the change of radiosonde took place in January 1963, the temperature anomaly was not apparent until after the Bali eruption several months later. The 12-month running mean temperatures at 100 and 60 mb for both Woomera and Charleville are shown in

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† Z = G.M.T.

Figure 3. This presentation in the form of moving averages effectively removes the annual temperature variation while allowing the biennial cycle and the high temperatures during 1963–64 to be seen. The time of occurence of the Bali volcanic eruption (March 17, 1963) is indicated in each figure.

As monthly mean temperatures are used here, it was useful to estimate the consistency (or relative accuracy) of data sampled in this way. Data from several

TABLE 1

POSITIONS OF STATIONS AND APPROXIMATE DATE OF CHANGE OF RADIOSONDE

Station	Latitude	Longitude	Sonde Changed
AUSTRALIA			
Adelaide	34° 57′ S.	138° 31′ E.	10. x.62
Alice Springs	23 48	133 53	25. xi.62
Carnarvon	24 53	119 39	11. i.63
Charleville	26 25	146 17	26. v.63
Cloncurry	20 40	140 30	10. vii.63
Cocos Island*	12 11	96 50	6. iv.63
Darwin	12 28	130 55	25. i.63
Garbutt	19 15	146 46	9. x.62
Guildford	31 56	115 57	14. v.63
Hobart	42 50	147 28	26. ii.63
Honiara*	9 25	159 58	20. v.63
Lae*	6 43	147 00	3. iv.63
Laverton	37 52	144 46	13. iii.63
Port Hedland*	20 23	118 37	24. iii.63
Williamtown	32 48	151 51	29. xii.62
Willis	49 59	160 18	20.viii.63
Woomera	31 20	135 55	15. i.63
NEW ZEALAND			
Auckland	36 51	174 46	20. ii.62
Christchurch	43 29	172 32	20. ii.62
Invercargill	46 25	168 19	27. ii.62
Nandi (Fiji)	17 45	177 27	17. iii.62
ANTARCTICA			
Amundsen–Scott	90 00	—	
Byrd	80 00	120 00 (W.)	
Hallett	72 12	170 12	
Wilkes	66 18	110 36	

* These stations use a 403 Mc/s radiosonde, while the other stations, in general, use 72 Mc/s. The Antarctic stations use GMD-1 equipment.

Antarctic stations ("Climatological Data for Antarctic Stations"*) were examined for those stations making twice-daily temperature soundings. Although the observations were made usually at 12-hourly intervals, it was considered that at these latitudes both radiation corrections to the sonde and diurnal temperature fluctuations should be negligible. Comparison of the monthly means for the two release times showed

* Published at intervals by the United States Weather Bureau, Washington, D.C.

that, in general, when the number of observations is greater than, say, 15, the difference between the two means seldom exceeds 0·5 degC. However, when the number of observations at one or other of the release times is less than 10, the difference often amounts to more than 1 degC. These observations appear consistent

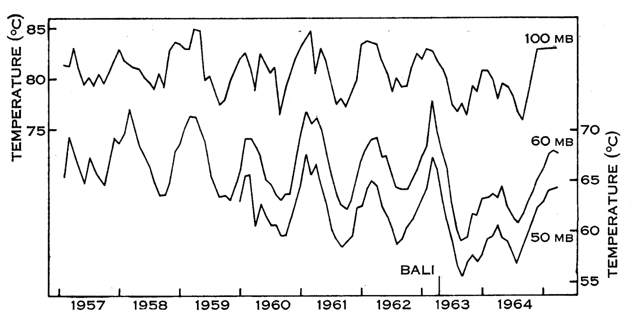

Fig. 1.—Monthly mean 2300 Z temperatures for Darwin at 100, 60, and 50 mb. The temperature scale (negative) is shown at left for 100 mb and at right for 60 and 50 mb. The time of occurrence of the Bali eruption is indicated.

with the daily temperature fluctuations that have been examined both for these Antarctic stations and, of course, for the Australian stations.

Temperature data above 60 mb were not recorded in Australia prior to November 1959. Sufficient 60 mb data (more than 10 observations per month) are available at most stations to enable examination of several years prior to 1959.

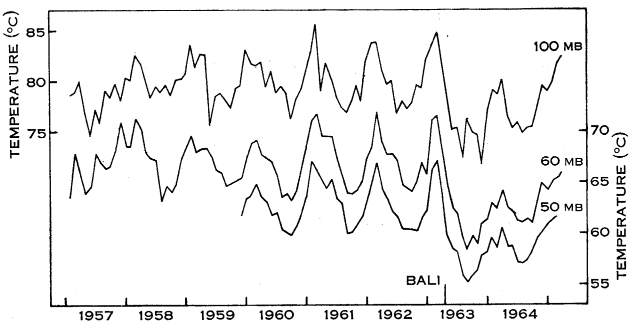

Fig. 2.—Monthly mean 2300 Z temperatures for Port Hedland at 100, 60, and 50 mb. The temperature scale (negative) is shown at left for 100 mb and at right for 60 and 50 mb. The time of occurrence of the Bali eruption is indicated.

However, it should be noted that, although the sparseness of data at 60 mb for some months gives rise to an "uncertainty" of perhaps 1 or 2 degC in the mean value for that month, it is unlikely that this uncertainty will be biased in either direction. Thus, the use of extensive smoothing (for example, 12-month running means) should make it possible to consider those months having more than 10 observations per month.

Where this criterion cannot be fulfilled, the value for that month has been obtained by linear interpolation between adjacent months.

The scheduled time of the daily release of the radiosonde has changed during the period being discussed (1953–65), being successively at 0400, 0330, and now at 2300 Z. The last change took place at about June 1957. The data prior to 1953 have been examined, but the sonde release time (0830 or 0730 Z) during that period makes the application of the radiation correction (discussed below) difficult. Similarly, several of the stations have changed their locations (and names) since 1953; however in each

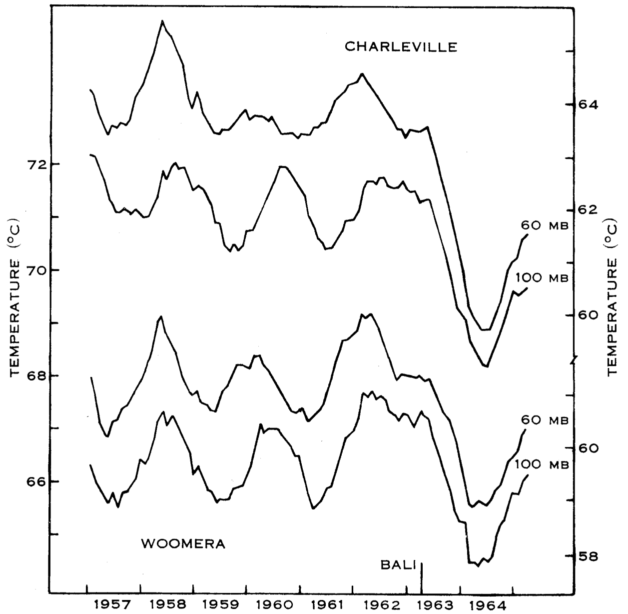

Fig. 3.—Twelve-month running mean temperatures for Charleville (top) and Woomera (bottom) at 60 and 100 mb. The temperature scale (negative) is shown at left for 100 mb and at right for 60 mb. Data for January–December are plotted as December. The time of occurrence of the Bali eruption is indicated.

case the new station is within a few miles of the previous one, so this positional change has been ignored. From 1957 until the change of radiosonde occurred, the radiation correction (see "Manual of Radiosonde Observations, Circular P"; United States Weather Bureau 1950) was applied to the daily observations by the observer at each station. For the data prior to 1957, the author has applied the radiation correction to the monthly mean data, based upon station latitude and longitude, time of year, and a mean rate of rise of the sonde. The corrections applied to the temperatures at several of the stations are illustrated in Table 2, where the radiation corrections at 60 and 100 mb are given for a month typical of each season.

The question remains whether the anomalously high temperatures indicated during 1963–64 are due simply to the lack of compatibility of the data taken from the two types of sonde, or to a real change in stratospheric temperature. That the former is unlikely is seen when it is realized that this infers the necessity for a radiation correction of several degrees to be applied to temperatures measured with the external white-coated thermistor. Unfortunately, night-time observations have been taken at only a few of the more southerly stations, and continuously only since late 1962. Insufficient night-time observations do not allow satisfactory comparison of the monthly means. This comparison would have enabled a check to be made on whether the new radiosonde was free of radiation errors.

Nevertheless, as the Australian radiosonde uses the same white thermistor and is built to the specifications of the equivalent United States Weather Bureau sonde, it is unlikely that the two sondes will exhibit different properties. The previous ducted-thermistor sonde should also be comparable to the sonde used in the United States. Teweles and Finger (1960) and McBirney (personal communication) give the radiation error in the exposed thermistor sonde as less than 1 degC at the heights

Table 2

RADIATION CORRECTIONS APPLIED TO MONTHLY MEAN TEMPERATURES AT 60 AND 100 MB FOR THREE OF THE STATIONS

	Darwin		Guildford		Laverton	
	60 mb	100 mb	60 mb	100 mb	60 mb	100 mb
January	4·4°C	2·4°C	4·7°C	2·6°C	4·2°C	2·3°C
April	4·2	2·3	3·7	2·0	3·2	1·8
July	3·8	2·1	3·3	1·9	2·6	1·5
October	4·4	2·5	4·4	2·4	3·8	2·1

considered here. Rofe (1963) has assessed the various sources of error inherent in the measurement of temperature with the ducted-thermistor sonde, and gives a combined standard error at these heights of the order of 1·5 degC.

The data for three of the New Zealand stations also show an anomaly during 1963–64. In Figure 4, the 30 and 50 mb running means for Auckland and Christchurch are shown. In these graphs, the anomaly appears as a breakdown in the biennial cycle, the temperature being several degrees higher than one might have expected. At Nandi, Fiji, no definite change could be seen; the biennial cycle also could not be seen. At lower heights (100 and 200 mb) for all of these stations, again no definite change could be seen.

Examination of the temperature records from a large number of stations in the northern hemisphere failed to reveal the anomaly shown above for the Australian and New Zealand stations. Unfortunately, suitable data from South America and South Africa have not yet become available to the author.

III. Total Ozone Amounts

The total ozone data from Aspendale (38·0° S., 145·1° E.) and Brisbane (27·5° S., 153·0° E.) are shown in Figure 5. It is again seen that anomalous values have been obtained in 1963–64. This is noticed as an apparent breakdown of the biennial oscillation in total ozone reported by Funk and Garnham (1962). On the other

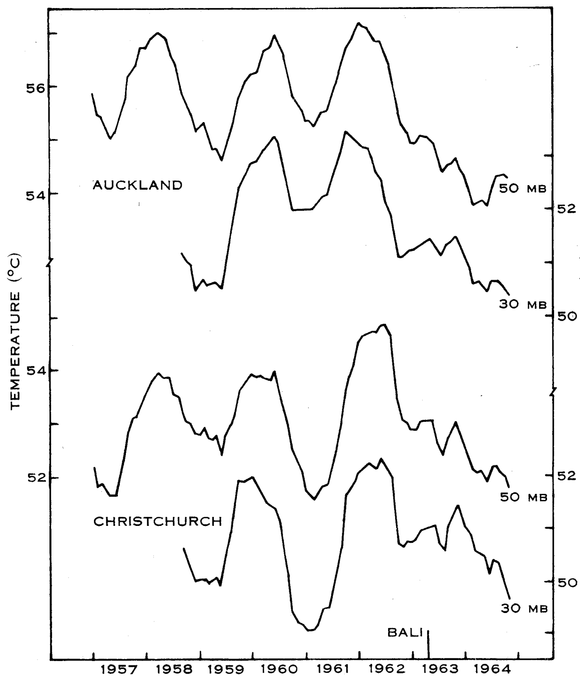

Fig. 4.—Twelve-month running mean temperatures for Auckland (top) and Christchurch (bottom) at 30 and 50 mb. The temperature scale (negative) is shown at left for 50 mb and at right for 30 mb. Data for January–December are plotted as December. The time of occurrence of the Bali eruption is indicated.

hand, it was found that the similar data for the Indian stations New Delhi (28·6° N., 77·2° E.), Ahmedabad–Mount Abu (24·5° N., 72·7° E.), and Kodaikanal (10·2° N.,

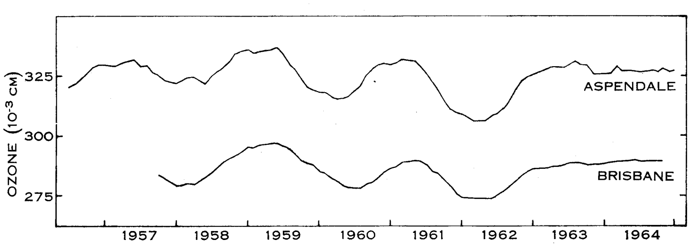

Fig. 5.—Twelve-month running means of total ozone amount at Aspendale and at Brisbane. Data for January–December are plotted as December.

77·5° E.) showed no significant change during 1963–64. It would appear that the anomaly occurred only in the southern hemisphere. It is interesting to speculate whether these effects could have been due to the presence in the stratosphere of considerable amounts of volcanic debris from the Mount Agung eruption, which occurred on March 17, 1963, or alternatively, whether the anomaly may just reflect a change in the nature of the quasi-biennial oscillation.

IV. Volcanic Debris from the Mount Agung Eruption

The volcanic dust from the Mount Agung eruption spread rapidly throughout the southern hemisphere, although taking a longer time to diffuse into the northern hemisphere. Photometric observations (and the occurrence of brilliant sunsets) showed that the dust had reached Chile, South Africa, and New Zealand within a month or so of the eruption (Hill 1964) and had spread throughout Australia (Hogg 1963; Harris 1965). Diffusion of the ash into the northern hemisphere did not occur until September or October 1963. Mossop (1964), using particle impactors on U-2 aircraft, has made collections of the volcanic dust over Australia. He has reported that the ash was present in appreciable quantities in early April 1963 and persisted for over a year. It has been reported that the presence of this ash at high levels depressed the amount of direct solar radiation received at the ground in New Zealand and Fiji by as much as 5% in comparison with previous years (Hogg 1963). Even larger depletion of solar radiation had been recorded for the Katmai and Krakatoa eruptions (Wexler 1951). Dyer (personal communication) has reported a depletion of direct sunlight of some 25% over Aspendale after the Bali eruption. The effects of volcanic dust on insolation and surface weather have been discussed by Wexler (1951).

It is difficult at this stage to postulate any definite mechanism whereby volcanic dust could affect the stratospheric temperature. Stagg (1964), in discussing the similar problem of the effects of rocket exhausts, was unable to decide the direction that any climatic change might take. However, Pittock (1964) has suggested the direct destruction of stratospheric ozone by a thin layer of volcanic dust. He has invoked this mechanism to explain a persistent dip, at 50 mb, in the vertical ozone distribution during March 1964 over Colorado, U.S.A. It is conceivable that this mechanism may be of importance particularly if the dust is in highly stratified layers. Kroening (1965) has also suggested the importance of direct ozone destruction by dust in the lower stratosphere.

V. Quasi-biennial Temperature Oscillation

The quasi-biennial oscillation (henceforth called biennial, for simplicity) in stratospheric temperatures was first reported by Ebdon and Veryard (1961). Since that time the characteristics of the oscillation in the tropical regions have been extensively studied. However, the picture in mid latitudes has not yet been firmly established. Indeed, it would seem surprising that more attention has not been paid to the data available in the southern hemisphere. Although these data are not as extensive as those for the northern hemisphere, it is apparent that the biennial oscillation is more clearly defined in the southern hemisphere (Reed 1965). Angell and Korshover (1964) have studied the data from a small number of stations in the southern hemisphere but have considered only two in the Australian region. For this reason, it seemed desirable to study the records of those stations in Australia having records of any significant length. As mentioned previously, data above 60 mb were not recorded in Australia prior to 1959. However, sufficient data are available at 60 mb to enable the comparisons shown in Figure 6 to be made. In this figure, the 12-month running means of the 60 mb temperatures (50 mb in the case of Canton Island, Hallett, and Wilkes) are shown, covering a range of latitudes from 3° to 72° S. (see

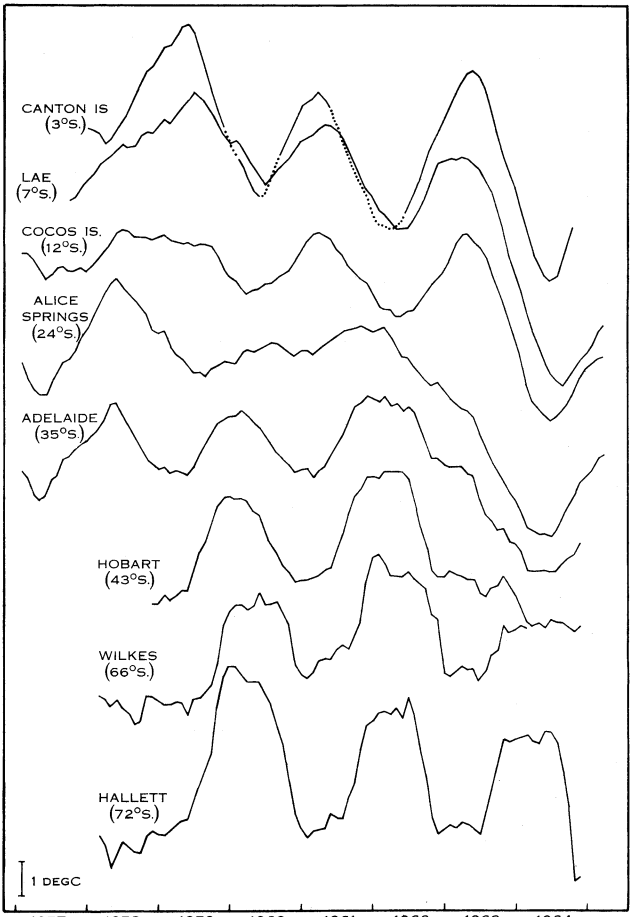

Fig. 6.—Twelve-month running means of 60 mb temperatures (50 mb in the case of Canton, Wilkes, and Hallett). Data for January–December are plotted as December. The temperature scale is indicated at lower left, negative magnitude increasing upward.

also Figs. 3 and 4). It is interesting to compare these graphs with similar ones for different longitudes, as shown by Angell and Korshover (1964).

Figure 6 shows clearly the rather abrupt phase change in the vicinity of 15°–20° S. The three stations equatorwards of this latitude are in phase with one another; the stations of higher latitude are in phase with one another but approximately 180° out of phase with the three "equatorial" stations. The amplitude of the oscillation decreases from the equator to a latitude of about 20° S., but then increases again at higher latitudes. Comparison of the phases of the New Zealand and Australian stations shows no significant difference, in agreement with the observation of Angell and Korshover of the invariance of phase with respect to longitude. Examination of the data at lower levels for Canton Island shows that the magnitude of the oscillation decreases rapidly with decreasing height, so that it has almost disappeared at 200 mb. Downward phase propagation of about 1 km per month is also seen, similar to that for the zonal wind oscillation. However, this phase propagation disappears southward of about 15° or 20° S., the oscillation then appearing in phase at all levels. At mid latitudes over Australia, an oscillation is still apparent at 200 mb at most stations. It is interesting to note, however, that these oscillations at 200 mb have a period significantly longer than 2 yr, and would appear to be closer to $3\frac{1}{2}$ yr. Further poleward, at Wilkes, the biennial oscillation is readily apparent at all heights between 50 and 200 mb.

The ozone and temperature cycles are more or less in phase, low temperature being coincident with low total ozone amounts. It has been shown previously (Sparrow and Unthank 1964) that, at the same time, the zonal wind cycle has its strongest west winds.

At the present time, data are available to study the biennial temperature oscillation only for a limited number of years. Thus it would not be altogether surprising if the apparent anomaly during 1963–64 were a change in the biennial cycle related to the solar sunspot minimum occurring during the same period. However, the anomaly did not appear in the northern hemisphere, nor has a similar anomaly been reported in the northern hemisphere for those stations with observations extending back to the previous solar minimum.

VI. Conclusion

It has been shown that, during 1963–64, temperatures in the lower stratosphere over Australia and New Zealand were several degrees higher than usual. Furthermore, total ozone amounts over Australia showed a similar increase. It has been suggested that these effects may be related to the presence in the stratosphere of volcanic debris from the Mount Agung eruption, or to a change in the nature of the biennial oscillation occurring during solar minimum.

VII. Acknowledgments

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