Australian ozone observations and a suggested 24 month cycle

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ABSTRACT

Ozone observational results for Aspendale, Lat. 38°02′ S (6½ yrs), Brisbane, Lat. 27°28′ S (5 yrs) and Macquarie Island, Lat. 54°29′ S (1 yr) are discussed. Compared to stations of similar latitude in the northern hemisphere the interdiurnal variation was found to be considerably smaller and the seasonal variation more regular. In addition Aspendale and Brisbane showed a distinct 24 month cycle. This cycle seems to be caused by changes in the stratospheric subsidence pattern rather than by synoptic scale advection.
Some improvements in calibrational and observational procedure are mentioned as well as modification to the spectrophotometer itself.

Ozone observations with standard Dobson Spectrophotometer were begun at Aspendale near Melbourne (Lat. 38°02′ S, Long. 145°06′ E) in July 1955 and at Brisbane (Lat. 27°28′ S, Long. 153°02′ E) in February 1957 and are being continued. Macquarie Island (Lat. 54°29′ S, Long. 158°58′ E) observations were restricted to the period April 1957 to February 1959 due to the untimely destruction of the instrument by fire. In addition some isolated readings were taken at Salisbury (Lat. 34°43′ S, Long. 138°39′ E). Essentially readings at Aspendale were taken daily at $\mu = 2,3$ and LAN,[1] and at Brisbane at 0900 hours daily, except at weekends. Readings at Macquarie Island, where climatic conditions are adverse, were taken whenever practicable. The instruments were standard pre-war Dobson Spectrophotometers modified for photomultipliers.[2]

Spectrophotometer calibrations and observational procedures

The observational and calibration procedures were essentially those laid down in Annals of the IGY, V. 5, Part I (1957), and by Dobson & Normand (1958) with the exception of the zenith blue and cloud corrections, and the two-lamp method.

[1] The notation and terminology are those used in Annals IGY, V. 5, Part I (also Observers' Handbook).

[2] For details of modifications see Appendix. An additional Instrument No. 78 was bought in 1960 but so far not used for routine observations.

Prior to 1960 ZB and cloud readings were taken on AD and CC′ pairs of wavelengths using corrected charts I_{AD}, I_C, II_C, and III (supplied by Beck, London) but from 1960 onward a simpler and more satisfactory method suggested by Stranz (1960) was used.

Stranz (1960), continuing on a suggestion made by Dobson, found that, if for an AD ZB reading an x is at first computed as though it were a DS reading ($x_{AD}^{*ZB} = (N_A - N_D)/1.388\ \mu - 0.009$) and x_{AD}^{*ZB} now compared with x obtained from an actual DS reading, then the difference $\Delta x_{AD} = x_{AD}^{DS} - x_{AD}^{*ZB}$ does not depend significantly on x. He was thus able to draw one single graph (Fig. 1) for Δx_{AD} versus μ. For very low μ's this chart, like all other ZB correction methods, should evidently not be used on account of the strong and essentially white, forward scattering of haze. This has the effect of changing the appearance of the near solar region for comparatively small changes in haze amounts, making it more or less similar to the sun itself, but this is of little practical interest, since under such conditions the sun itself would most likely be visible, permitting the preferable DS readings. The ZB correction chart, when applied to the DS and ZB comparison data, gave the following error frequency ($1.3 < \mu < 3$):

Error, %	≤1	≤2	≤3
Frequency, %			
Aspendale	69	98	100
Brisbane	81	97	100

For cloud readings no additional correction had to be applied to the ZB correction, except

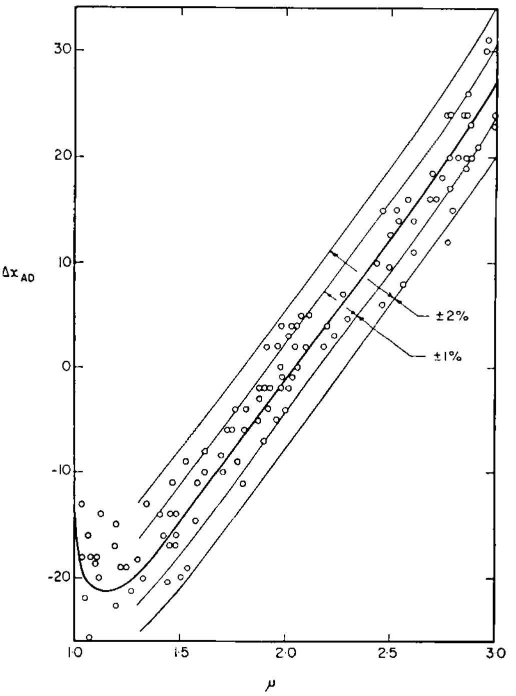

FIG. 1. Inst. No. 12: AD Zenith Correction Chart. $\Delta x_{AD} = x_{DS}^{AD} - x_{ZB}^{*AD}$.

for low cloud, where only an overall correction of -0.005 cm was required. The following error frequency was found:

Error, %	⩽1	⩽2	⩽3	⩽4
Frequency, %				
High and middle cloud	52	90	100	
Low cloud	43	73	97	100

These results are considerably better than those obtained by standard methods both here and elsewhere (KINISKY *et al.*, 1961) and in addition the method is very much simpler to use.

For both absolute and relative wedge calibration the perforated-plate method (FUNK, 1959) was used. Apart from being much easier to employ than the two-lamp method, light in the latter method does not enter the instrument perpendicular to the ground quartz plate as in normal use but more obliquely, which is undesirable. The following small but consistent difference between the mean absolute calibration obtained by the two methods presumably attributable to this cause was found.

Instrument no.	12	78
Perforated-plate minus two-lamp method (log-units)	0.002	0.003

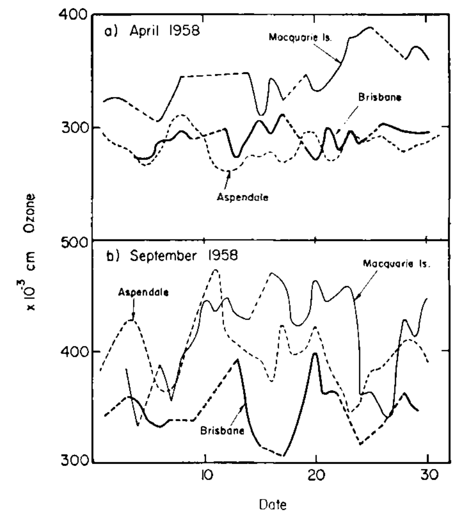

FIG. 2. Typical daily ozone values over Brisbane, Aspendale and Macquarie Island. (*a*) Autumn minimum; (*b*) Spring maximum.

Observational results

(*a*) DAILY VARIATION

Fig. 2 shows typical daily ozone values over Aspendale, Brisbane and Macquarie Island during the spring maximum and autumn minimum. Aspendale and Brisbane show considerably less interdiurnal variation than stations in the northern hemisphere of comparable latitude (see e.g. KULKARNI *et al.*, 1959; KOMHYR & MATEER, 1961) but the frequency spectrum seems similar; Macquarie Island also shows this to a small degree. Furthermore, as a comparison of daily ozone values over Aspendale and Salisbury shows there seems to be a high correlation between stations up to several hundred km distance in the middle latitudes, a phenomenon which again does not seem to be so pronounced in the northern hemisphere. However, Melbourne and Brisbane are no longer significantly correlated (correlation coefficient ≈ -0.1).

(*b*) SEASONAL VARIATION AND 24 MONTH PERIOD

Table 1 gives monthly mean values for the Australian stations for the period, 1955–1961, whilst the same data with the addition of Kodaikanal (Lat. 10°14′ N, Long. 77°28′ E) are presented graphically on Fig. 3.

Here again the far more regular, yearly cycle compared to similar latitudes in the northern hemisphere (see e.g. KULKARNI *et al.*, loc. cit.) is apparent.

TABLE 1. *Ozone monthly means.*

	Aspendale[a]							Brisbane[b]						Macquarie Island[c]			
Month	1955	1956	1957	1958	1959	1960	1961	1956	1957	1958	1959	1960	1961	1957	1958	1959	1960
Jan.		305	298	316	297	295	302		277	279	274	261	272		341		
Feb.		292	286	295	304	289	304		251	260	272	247	267		311	Nil	Nil
Mar.		276	295	297	301	289	283		272	269	276	259	263		354		
Apr.		285	302	282	282	286	285		265	281	286	265	271		342		
May		303	309	296	310	319	291		263	283	284	271	263		344		
June		349	308	347	320	340	309		270	293	278	277	261		398		
July	335	350	350	375	319	354	315		275	302	287	292	272	356	386		
Aug.	356	378	353	369	339	385	336		292	310	282	303	283	353	414		
Sept.	345	379	364	399	352	386	329		314	335	302	311	289	373	418		
Oct.	351	374	349	386	349	366	335	318	302	316	305	325	295	442	449		
Nov.	330	344	332	345	322	335	315	306	282	305	296	329	282	381	409		
Dec.	320	321	318	328	320	315	302	303	288	311	285	294	278	Nil	369		

[a] Lat. 38°02′ S Long. 145°06′ E. [b] Lat. 27°28′ S Long. 153°02′ E. [c] Lat. 54°29′ S Long. 158°58′ E.

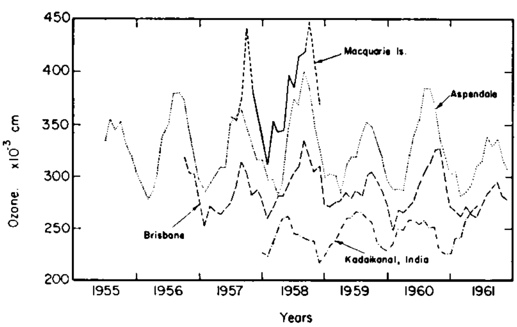

FIG. 3. Ozone monthly means for Australian stations and Kodaikanal (from *Indian J. Met. Geophys.*)

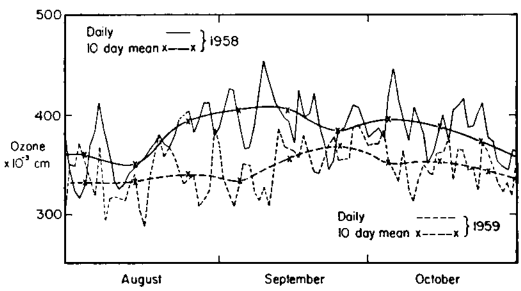

FIG. 5. Comparison of daily ozone values during years of high and low spring maximum.

In addition both Aspendale and Brisbane show a regular pattern of high spring maxima alternating with low ones. The autumn minima are nearly enough equal each year. No such pattern is shown in the Kodaikanal values. By taking 12 month overlapping means this pattern is shown even more clearly on Fig. 4. As far as one can tell, there does not seem to be any worthwhile phase difference between Melbourne and Brisbane.

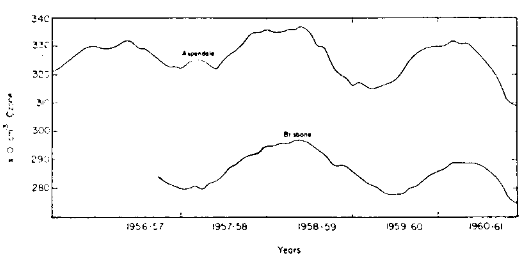

FIG. 4. Overlapping 12 month means of ozone for Aspendale and Brisbane.

From a comparison of three typical months during a year of high spring maximum with similar ones occurring during a year of low spring maximum (see Fig. 5) it is apparent that the high monthly means are not the result of a few excessively high values, but of a generally higher level of ozone.

Discussion

The more regular ozone pattern both as regards daily and monthly variation at one station in Australia (to a lesser extent Macquarie Island) compared to that in the northern hemisphere is to be expected, since the ozone values over higher latitudes during the spring maximum are lower (MACDOWALL, 1960) and it may also be that the trajectories in the southern hemisphere do not extend to such high latitudes—the standard vector deviation of the stratospheric wind in the two hemispheres seems rather similar (TUCKER, 1960).

The suggested 24 month cycle seems to be caused by changes in the general subsidence pattern of ozone-rich stratospheric air rather than by synoptic scale advection from regions of differing ozone concentration, since it is the general level of ozone and not the fluctuations which cause the higher or lower ozone values. Also the fact that only the spring maximum is affected and not the autumn minimum suggests this, since subsidence seems to be far more important in spring than in autumn (MURGATROYD & SINGLETON, 1961; GOLDSMITH & BROWN, 1961). In addition there seems to be an indication of a two year cycle in the sudden warming in the antarctic stratosphere (GRAY, 1961).

This ozone cycle does not seem to have been observed in the northern hemisphere. It might, however, have been obscured there by the greater variability of ozone. On the other hand, as far as one can tell from the Kodaikanal observations, this cycle does not seem to extend to lower northern latitudes.

It is hoped that observations at Macquarie Island will be resumed and will shed valuable further light on this question.

In conclusion it may be said that the pattern of ozone over Australia and Macquarie Island and presumably in general over similar latitudes in the southern hemisphere is markedly different from that over similar latitudes in the northern with regard not only to latitudinal (MACDOWALL, loc. cit.) but also to seasonal and diurnal variation.

Appendix

The following modifications, which are essentially different from the current model of the spectrophotometer, were carried out.

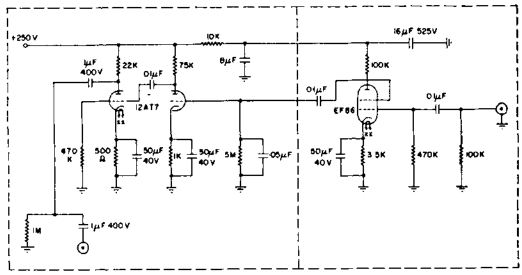

FIG. 6. Wiring diagram for redesigned spectrophotometer amplifier.

1. The amplifier was redesigned for higher gain and lower noise.[1] The wiring diagram is shown on Fig. 6.
2. The commutator brushes which were found to have a tendency to wear grooves into the commutator and to create carbon dust settling on optical parts of the instrument were replaced by cam-operated ignition contacts normally used in cars.
3. The mounting of the achromatising lenses before and after S4 was strengthened, since it was found that with the original mounting standard lamp readings on C long were drifting far more than on other wavelengths.

These modifications improved the performance of the instrument considerably.

Acknowledgements

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Our thanks are further due to the Bureau of Meteorology for carrying out the Brisbane Ozone observations and to the ANARE for setting up and operating the instrument at Macquarie Island.

REFERENCES

ANNALS OF THE IGY, 1957, V. 5, Part I, pp. 1–114, Pergamon Press.

DOBSON, G. M. B., and NORMAND, C., 1958, *Determination of constants etc. used in the calculation of the amount of ozone from spectrophotometer measurements and an analysis of the accuracy of the results*, pp. 45, I.A.M.A.P., Oct. 1958.

FUNK, J. P., 1959, *Journal Scient. Instr.* **36**, 378.

GOLDSMITH, P. and BROWN, F., 1961, *Nature* **191**, 1033.

GRAY, T. I., 1961, Personal communication.

[1] Spraying of all HT parts, particularly those around the photomultiplier, with silicone insulation lacquer is also very effective in reducing noise.

KINISKY, J. J., KOMHYR, W. D., and MATEER, C. L., 1961, *Can. Met. Mem.*, No. **8**, Met. Branch, Toronto. (See also *Can. Met. Mem.*, Nos. **6** and **7**.)

KULKARNI, R. N., ANGREJI, P. D. and RAMANATHAN, K. R., 1959, *Papers in Met. and Geophys.*, **10**, 85.

MACDOWALL, J., 1960, *Proc. Roy. Soc.* A, **256**, 149–197.

MURGATROYD, R. J., and SINGLETON, F., 1961, *Quart. J. Roy. Met. Soc.*, **87**, 125.

STRANZ, D., 1960, Personal communication.

TUCKER, G. B., 1960, *Geophys. Mem.* No. **105**, V. **13**. Gt. Britain, Met. Office.