PRESIDENTIAL ADDRESS

by

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The 26-month cycle and atmospheric ozone

Three years have passed since our last symposium in August 1961 at Arosa. We now meet in another important centre of studies in atmospheric and space sciences, a centre where one of the pioneers of ozone research, Dr. V.H. Regener, is evolving new tools of remarkable delicacy and simplicity for studying ozone in the atmosphere. We are very grateful to President Popejoy and other authorities of the University of New Mexico for inviting us to meet at Albuquerque in these quiet and restful surroundings and making such excellent arrangements for our stay and work. We look forward to a very fruitful session.

1. The IGY-IGC years opened out new vistas in atmospheric and space sciences. A better appreciation of the role of ozone in atmospheric phenomena was one of the results. Ozone measurements helped to elucidate the phenomenon of sudden warmings of the stratosphere which had been first observed a dozen years ago in Europe. The existence of significant longitudinal difference in ozone amounts and the role of ozone as a tracer for studying stratosphere-troposphere interactions were firmly established. As a result, WMO and the national Meteorological Services have undertaken the responsibility for organizing regular measurements of atmospheric ozone and the publication of ozone data on a world-wide basis for promoting further research.

After the IGY, the programme of the IQSY (the International Quiet Sun Years) which includes synoptic studies of atmospheric ozone is now in action, and there is already evidence of the rich harvest which we may expect. A scheme of issuing alerts for sudden stratospheric warmings (STRATWARM) to enable simultaneous special ozone-sonde ascents is in operation. The network of total ozone stations has expanded considerably, particularly in North America and the U.S.S.R. About 15 ozone-sonde stations are now in operation, most of them in North America.

2. International comparisons of ozone sondes with ground-based methods for determining the vertical distribution of ozone were made at Arosa in the summer of 1961 and in the spring of 1962. They have shown up the relative values of the different techniques. Dr. Dütsch's report shows the high resolution and near equivalence of the new ozone sondes of Brewer and Regener, and the limitations and strength of the Umkehr method. In spite of the limited resolution of the Umkehr method, its undoubted value in estimating ozone amounts above 10 mb and studying the long-term variations of ozone in the ozone production region remains. Computer methods of Umkehr calculation have been perfected by Dr. Dütsch and Dr. Mateer and improvement in calculating the effects of multiple scattering have been made by Dr. Dave. Dr. Vigroux has pursued his studies of the determination of the smoothed vertical distribution of ozone by infra-red measurements of the 9.6μ band. The infra-red method, however, seems to have serious limitations in determining the detailed structure of ozone distribution.

A combination of the chemical or chemiluminescent ozone sonde (for detailed structure up to the maximum balloon height) and of the simple optical filter sonde for the total ozone amount above the maximum balloon level seems to be the ultimate solution.

Proc. Ozone. Symp. Albuquerque, 1964, 1-6, World Meteorological Organisation, Geneva, 1965.

3. Professor Dobson is continuing his efforts to improve the accuracy and reliability of total ozone measurements with the ozone spectrophotometer. By comparing the values of the absorption coefficients of ozone in the laboratory and in the atmosphere with the same spectrophotometer and the standard wavelengths, Dobson finds that the relative value of the differential absorption coefficient for wavelengths (3114/3234), now adopted from Vigroux's work, requires a substantial reduction. The modified values suggested by Dobson fit in well with the results of simultaneous measurements on different wavelengths made in different parts of the world. Indeed, our observations at Ahmedabad and Kodaikanal show that, using the new absorption coefficients, it is possible to separate clearly the effect of ozone and of aerosols on the attenuation caused by the atmosphere on A, C and D wavelengths.

One of the uncertainties in the comparison of ozone measurements made with the Dobson spectrophotometer at different places and at different times is the correct determination of L_0, the wedge reading that would be obtained with direct sunlight outside the earth's atmosphere. Changes in the value of L_0 may occur due (1) to changes in solar radiation and/or (2) to changes within the instrument. If we had a constant, reproducible source of radiation for the region 3000 to 3450 Å, we could check the constancy of solar radiation. Professor Dobson finds that the new quartz-iodine lamps introduced by GEC, U.K. are remarkably constant in their radiation after a few hours of running, and after 100 hours show no detectable change. He has recommended the use of these lamps both for wedge-calibration and for monitoring the constancy of solar radiation. This has yet to be tried out.

4. I propose to devote the remaining part of my address to the recently discovered biennial variation of ozone, its connexion with the so-called 26-month equatorial stratospheric wind oscillation, its apparent connexion with geomagnetic activity, and some long-term abnormalities and possible relationship to solar activity. I shall also touch on the question whether nuclear explosions in the atmosphere affect atmospheric ozone.

The first clear evidence that there was a regular biennial variation of the total ozone amount came from the Australian observations - J.P. Funk and G.L. Garnham in a paper published in Tellus (14, 378-382, 1962) discussing the observations made at Aspendale (38°S, 6½ years) and Brisbane (27½°S, 5 years) showed that there was a distinct 24-month cycle in the ozone variations which could not be attributed to changes in synoptic weather. They surmised that this might be due to "changes in the general subsidence pattern of ozone-rich stratospheric air". At Ahmedabad, we examined the ozone observations made at Kodaikanal (10°N) during the same period, and found that there was a clear, though small, 24-monthly oscillation with its phase reversed. Further, on examining the observations made at other northern hemisphere stations, we found well-marked oscillations at Abu-Ahmedabad, Delhi, Tateno, Elmas and Rome.

Figures 1 to 5 show the phenomenon of biennial variations of ozone and of the related equatorial stratospheric winds.

The two-year cycle covers a wide range of latitudes on either side of the equator, both north and south. The equatorial zonal wind oscillation at 50 to 30 mb is consistent with the idea that there is a superposed thermal gradient below those levels, with temperatures increasing with increasing ozone amounts. The biennial variation means that once the additional ozone molecules get into the protected region of the tropical stratosphere below 25 km, some of the excess can remain there for more than a year and less than two years. More collection and analysis of stratospheric wind data over tropical and subtropical latitudes are called for.

Although the normal cycle has a period of two years, there are breaks in the cycle - as in 1962-1963. There have apparently been other breaks previously, as can be seen from an examination of the long series of Arosa data from 1939 to 1963. The abnormal behaviour in 1952 and 1941 may be seen from Figure 6. This suggests an 11-year period for the abnormality, occurring about half-way between two solar maxima. It has often been asked if the ozone amount is affected by geomagnetic activity.

Professor Dobson and his colleagues attempted to answer this question by comparing daily values of ozone with the magnetic character figure of the same day or preceding days, using the ozone data of Oxford only, and again using the data of a number of stations in north-west Europe. Dr. Kulkarni in Australia and Dr. Sekihara in Japan have attacked the same problem in a somewhat similar way.

With a view to reducing the meteorological effects, Mr. Angreji of our laboratory has correlated the two-year running means of ozone at a few stations in different latitudes with the running means of the international magnetic character figure (Ci) of the same two years.

Figure 7 shows the relation between overlapping two-year averages of O_3 against C_i at Tromsø (1939-1959), Oslo-Dombas or Lerwick (1940-1961), Arosa (1932-1961) and Abu-Ahmedabad (1952-1963). The data covering the period before 1949 when the observations were taken with a photo-cell in the spectrophotometer have been indicated by a different symbol. There is a definite effect at 70° and 60°, which becomes less and less pronounced as we approach the equator. There is yet another diagram prepared by Mr. Angreji showing the two-year means of O_3 (1958-1959) against (a) geographic latitude, and (b) magnetic dip latitude. The scatter of points is slightly less in the second curve.

Is it possible that in addition to ultra-violet light from the sun, energetic particles from the solar wind and associated X-rays which enter preferentially in the polar zones also dissociate O_2 and give rise to O_3 ? There is no clear evidence yet that wave radiations from solar flares increase the ozone amount.

There is another important question raised by the abnormal increases in ozone over a number of stations in 1959 and in 1962 (Figure 9). Are they due to the large-scale nuclear explosions in 1958 and their resumption in 1961 after the moratorium? The gradual degradation of high energy particle radiations and long-lived radioactive isotopes (both natural and man-made) in the protected ozone region can lead ultimately to the dissociation of O_2 into O and the formation of some O_3. Quantitative calculations are necessary.

I have not touched on various other problems of great interest, such as satellite studies of ozone, photo-production and destruction of ozone, the connexion of ozone with OH and Na and airglow in the mesosphere, radiation problems and the very important question of the general circulation in the stratosphere and mesosphere to which the study of the distribution of ozone in the atmosphere and its variations is contributing.

Most of these questions will be discussed at our symposium.

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5. Kulkarni, R.N., - Nature, 198, p.1189 (1963).
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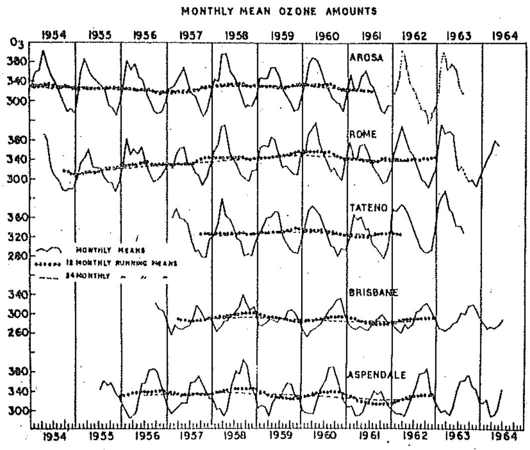

Figure 1 - Monthly mean ozone amounts over Aspendale, Brisbane, Tateno, Rome, Arosa (with 12-monthly and 24-monthly running means). Note the biennial variation and the change of phase which occurred at all the stations in 1963.

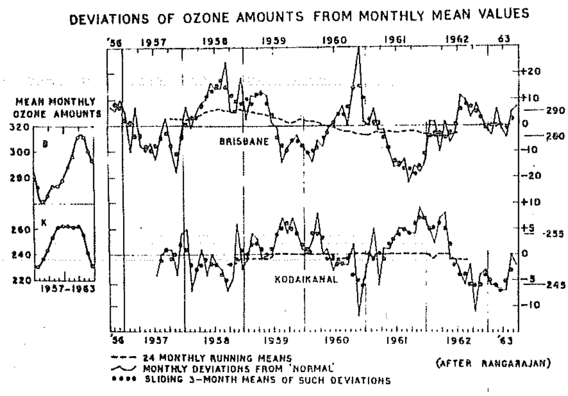

Figure 2 - Deviation of monthly (and three-monthly) means from average monthly or three-monthly means for the whole period 1957-1963, over Brisbane and Kodaikanal (Rangarajan, and Angreji). The deviations of ozone from the respective averages at Kodaikanal and Brisbane have opposite phases.

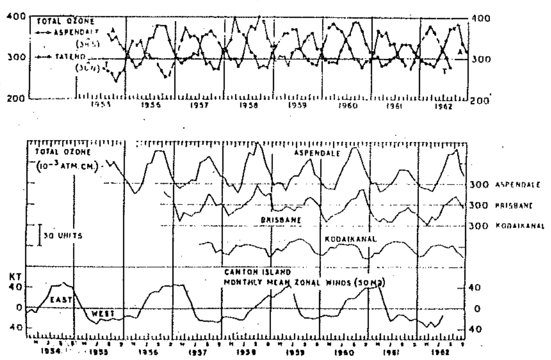

Figure 3 - Ozone amounts (monthly means) over Aspendale, Brisbane, Kodaikanal and Tateno, and equatorial winds at 50 mb over Canton Island. The 50 mb equatorial winds become easterly when the subtropical ozone amounts are decreasing, and westerly when they are increasing. It may be seen that the biennial increases occur in the same year at Tateno and Aspendale in the respective springs.

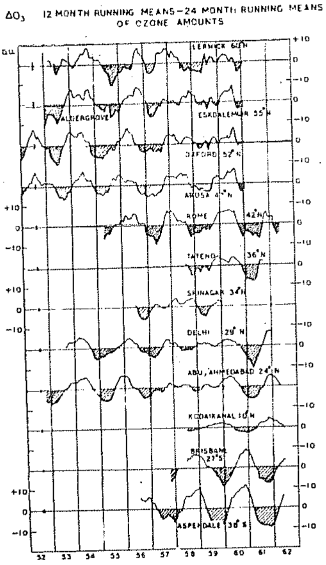

Figure 4 - 12-month minus 24-month running means of ozone over stations at different latitudes from Aspendale (30°S) to Lerwick (60°N). This diagram brings out the biennial variation from 38°S to 50°N more clearly. Note the abnormality in 1958-1959.

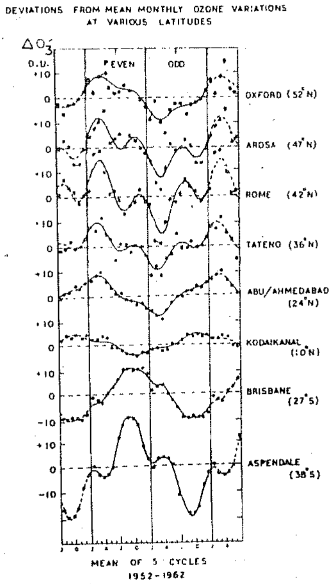

Figure 5 - Average biennial deviations of ozone amounts from mean monthly amounts at various places from 38°S to 52°N.

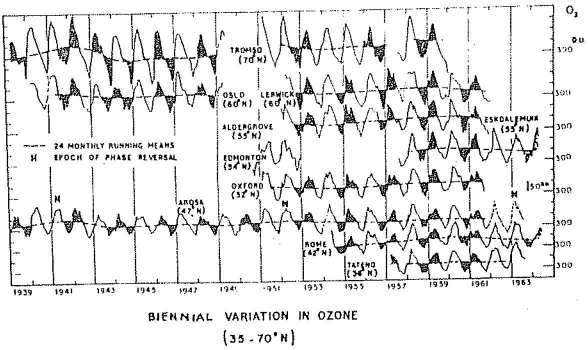

Figure 6 - Solar activity and phase changes in two-year cycle.

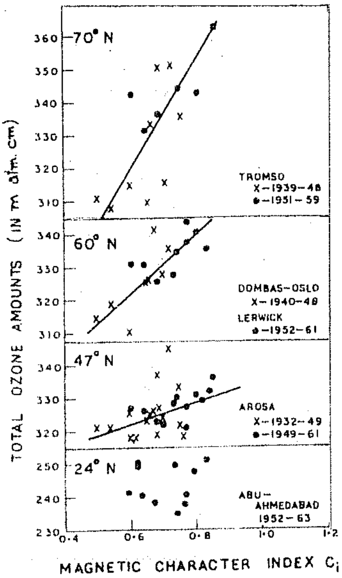

Figure 7 - Overlapping two-year means of ozone against two-year means of international magnetic character figure Ci at Tromsø, Dombas-Lerwick, Arosa and Abu-Ahmedabad.

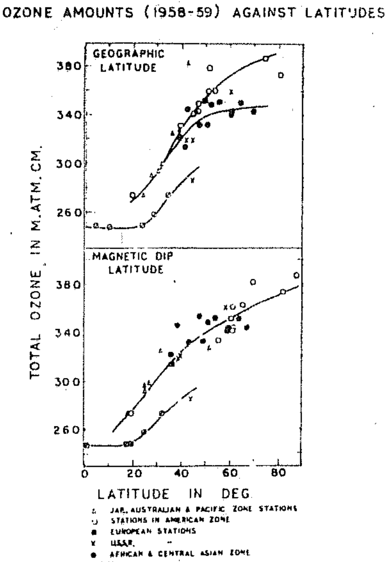

Figure 8 - Two-year means of ozone against (a) geographic latitude and (b) magnetic dip latitude. Sapporo seems to stand out with abnormally large ozone amounts.

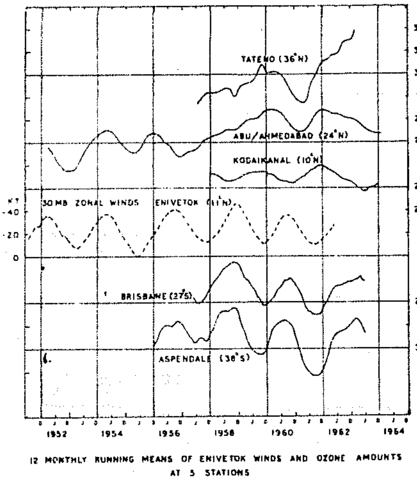

Figure 9 - 12-month running means of Eniwetok upper winds and ozone amounts at five stations. Note the abnormal changes of ozone at Ahmedabad and Tateno in 1958-1959 and at Tateno, Brisbane and Aspendale in 1962.