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Bi-annual variation of atmospheric ozone over the tropics

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SUMMARY

It is shown that there is a bi-annual variation of atmospheric ozone over equatorial, subtropical and lower middle latitude stations, a year of high ozone being followed by one of low ozone. A high ozone year in the sub-tropics and lower middle latitudes corresponds to a year of low ozone near the equator. A possible connexion of this with the bi-annual variation of zonal winds in the stratosphere of low latitudes is indicated.

1. INTRODUCTION

An unexpected fact about atmospheric movements which has been recently elucidated by the work of Ebdon (1960, 1961), Veryard and Ebdon (1961), and Reed *et al.* (1961), is the persistent prevalence successively in alternate years of easterly and westerly winds in the equatorial stratosphere at 18 to 30 km. There is also evidence that there is a bi-annual variation of temperature in the lower equatorial stratosphere, with lower temperatures in a year of easterly winds.

In this connexion, the following facts about the equatorial stratosphere may be recalled. Below 30 km, there is a strong upward gradient of ozone mixing ratio, and below 22 km, the ozone amount under conditions of photo-chemical equilibrium can be conserved for long periods of time of the order of a year and more. The winds at levels between 18 and 24 km over the tropics are generally weak. The question therefore arises whether there are any slow oscillatory changes in the ozone amount at these levels in the tropics and lower middle latitude stratosphere which may be responsible for year-to-year changes in temperature and consequently of thermal winds.

2. OZONE DATA

An examination of the ozone data of Indian, Australian, Japanese and Italian stations brings out the following facts.

(1) The total ozone amounts observed at Mt. Abu/Ahmedabad (25°-23°N) and of Kodaikanal (10°N) show a bi-annual variation. In years of excess ozone at Abu (even years), there is deficit of ozone at Kodaikanal and vice versa (Fig. 1). The ozone amounts at Delhi and Srinagar behave similarly to those at Abu/Ahmedabad, but there are some discrepancies in the Delhi ozone amounts which need further examination.

(2) The ozone amounts at Tateno*, Japan (36°N) and Rome (42°N) and Elmas (39°N) in Italy show the same bi-annual variation as that at Abu, but more clearly with larger amplitudes.

(3) The ozone amounts at Aspendale (38°S) and Brisbane (27°S) also show clear bi-annual variation, the years of excess ozone being the same as those at Tateno and Rome and alternate to those at Kodaikanal, but with the season of maximum displaced to the southern spring.

(4) An analysis of the vertical distribution of ozone over Aspendale by Kulkarni (1962) and that over Tateno shows that there is in general, for the same total ozone amount, more ozone at 18-24 km over Aspendale than over Tateno.

It may be mentioned that the ozone data of Shanghai (31°N) taken during the years 1937-42 show a similar bi-annual variation with excess ozone in even years as at Abu and Tateno. Arosa data do not show any obvious bi-annual variation, but a more detailed analysis is being made.

* The Tateno ozone data of 1955 and 1956 have been excluded from consideration, because of the following note published in *J. Aerol. Observatory*, Tateno, 6, No. 2, Annex 5; 'Before 21 February (1957), the condition of the instrument was 'insufficient.' In the period from 21 February to 30 June (1957) additional observations were made after the direction of the I.O.C.'

Quart. Journ. Roy. Met. Soc. 89, 540–542, 1963.

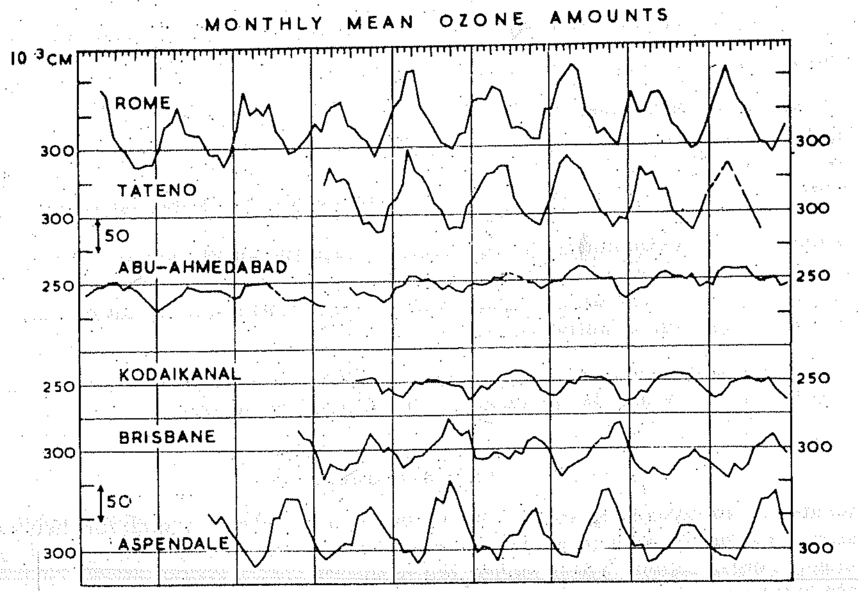

Figure 1.

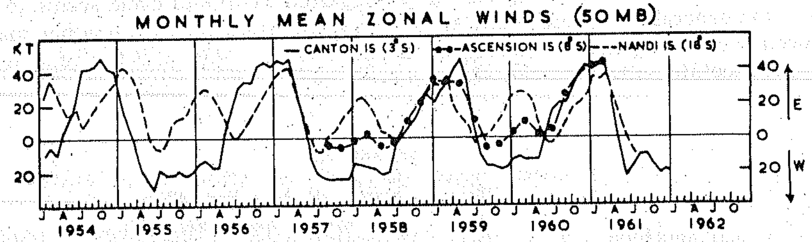

Figure 2.

In Fig. 2, the zonal components of wind at 50 mb over Canton Island (3°S), Ascension Is. (8°S), and Nandi (18°S) are shown (after Ebdon (1961) and Farkas (1961)). At Ascension, the easterly winds die out in alternate years, while at Nandi in the Fijis, they remain westerly, but weaken.

The following interesting relationships emerge :

(a) A year of high ozone in the sub-tropics and lower middle latitudes is also a year of low ozone over Kodaikanal.

(b) The succeeding year of low ozone in the sub-tropics is a year of high ozone over the equator (represented by Kodaikanal).

Easterly winds prevail over the Equator when the equatorial ozone amount is increasing (and mid-latitude ozone amount is decreasing), and westerly winds when the equatorial ozone is decreasing (and mid-latitude ozone amount is increasing). The alternating change in the equatorial wind system commences each year sometime in the northern spring.

The problem is complex, but the following is a tentative picture.

Persistent easterly winds over the equator at 18-24 km would, owing to tendency to conserve angular momentum, produce slow descent from above (where ozone mixing ratio is higher) and some inflow from the stratospheric ozone reservoir in higher latitudes, causing an increase in ozone amount. The increased ozone will warm up the lower equatorial stratosphere (Hitschfeld and Houghton 1961) and change the stratospheric winds to westerly. This will lead to upward movement, outflow of air to higher latitudes, loss of ozone, cooling and re-establishment of equatorial easterly winds. The bi-annual periodicity of winds and ozone suggests that one year is too short a time for the meridional inter-mixing of air between the equatorial and middle-latitude lower stratosphere, but that two years are enough.

3. Bi-annual sequence of events at 18-24 km over the tropical tropopause

Summarizing, the suggested sequence is as follows:

Thermal geostrophic *easterly* winds.

Downward movement of air over the equator and equatorward transport from middle latitudes.

Increase of ozone over equator in the photo-chemically protected region and decrease over sub-tropics.

Warming of lower equatorial stratosphere and westerly winds.

Upward movement of air over equator and poleward meridional flux of ozone.

Decrease of ozone over equator and increase over sub-tropics and lower middle latitudes.

Thermal geostrophic easterly winds.

We do not at present have enough upper wind and vertical ozone distribution data to check these suggestions. They may be forthcoming in the next few years.

Acknowledgments

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Since preparing this note the writer has seen the valuable Note by J. P. Funk and G. L. Garnham in *Tellus*, 1962, **14**, p. 379, entitled 'Australian ozone observations and a suggested 24-month cycle,' in which they remark, '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.'

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