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Measurements of the vertical distribution of Ozone by Umkehr effect at Hyderabad (17·4° N) during Spring 1961

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ABSTRACT. The vertical distribution of ozone over Hyderabad (17·4°N) has been measured by the Umkehr effect using a Dobson spectrophotometer during March-April 1961, on days when there were direct determinations with Paetzold ozone sondes sent up on balloons. Surface ozone at the time of launching of the balloons has also been measured by the chemical method using Ehmert's apparatus. These ground observations are described; and they are discussed in relation to prevalent meteorological conditions.

1. Introduction

During February to April 1961 a joint Indo-USA balloon flight programme was carried out from Hyderabad, India (Geographic latitude 17·4°N and longitude 78·4°E) for cosmic ray and geophysical observations. As part of this programme, Paetzold ozone sondes were sent up by scientists of the Geophysics Research Directorate (Air Force Cambridge Research Laboratories, U.S.A.) for measuring the vertical distribution of ozone in the atmosphere. On the days on which balloon ascent ozone distribution measurements were made, we measured the Umkehr effect with a Dobson spectrophotometer and also measured the surface ozone by the chemical method using Ehmert's apparatus. The results of these ground observations are reported in this note.

At Hyderabad there have been regular balloon programmes conducted by the Tata Institute of Fundamental Research over the first half of each year during the years 1959 to 1963; this is a continuing programme. A large number of these ascents have attained altitudes of 30 km and above. From these flights, Gokhale *et al.* (*see* ref.) have obtained wind data at these altitudes at this latitude. They have reported on the approximately two-yearly reversal of winds at high altitude which has been observed at other low latitude stations. Ramanathan (1963) has shown that there is a relationship between the cyclic variation of ozone and the cyclic reversal of winds at high altitude, both of which are presumably connected with atmospheric heat input phenomena. In view of this it appears appropriate both to record herein the ozone data at Hyderabad and to continue to take such observations at this station since this is the one place in India where appreciable data concerning high altitude winds is being obtained.

For these observations a Dobson spectrophotometer (No. 39) belonging to the Council of Scientific and Industrial Research,

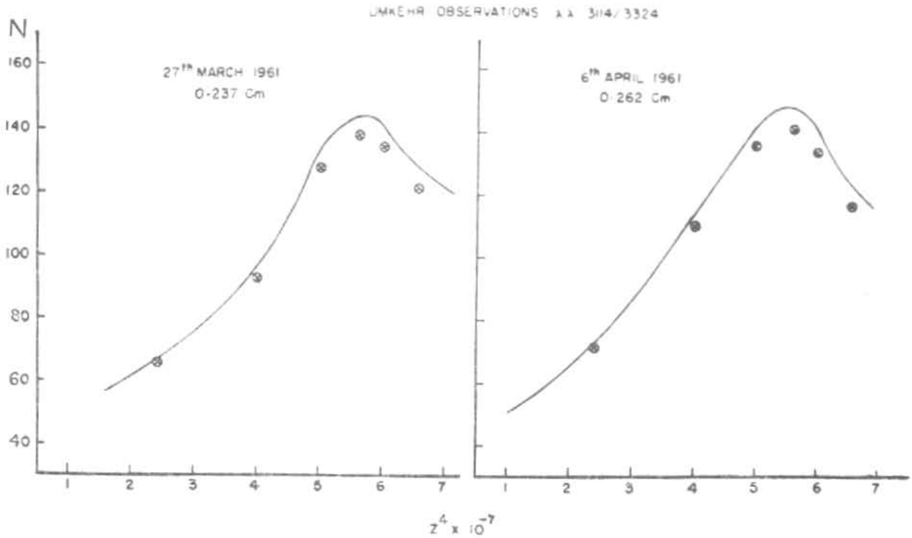

Fig. 1. Umkehr observations, λλ 3114/3324

Circles represent observed points after correction for secondary scattering; crosses represent calculated points. They are within the circles.

was transferred to Hyderabad from Kharagpur and was recalibrated. The extra-terrestrial constants were determined from observations on a number of clear days. Measurements on the Umkehr effect were made on the same day at the ozone sonde ascents; when clouding prevented observations on the same day they were taken on the succeeding day. The concentration of ozone at ground level was measured by Ehmert's apparatus approximately at the time of launching of the balloon.

2. Vertical distribution of ozone by the Umkehr effect

Method B of Gotz, Meetham and Dobson (1934) as described by Ramanathan and Dave (1957) in the IGY Instruction Manual was used for calculating the vertical distribution of ozone from the Umkehr observations. In this method, the observed total ozone content is distributed among a number of 6-km thick atmospheric layers by trial and error, in such a manner that the ratio (I/I') of intensities, I and I' in two narrow spectral bands, of the light coming from the zenith sky (measured at a number of zenith distances of the sun), as observed experimentally and calculated on the basis of the particular distribution of ozone agree within specified limits of observational error. The observations at Hyderabad were made on the wavelength pair (λλ 3114/3324), one of which (λ 3114) lies in the ozone absorption region and the other (λ 3324), just outside it. Fig. 1 shows sample Umkehr curves obtained on two days, 27 March and 6 April 1961 when the total ozone amounts were 0·237 cm and 0·262 cm respectively.

In the tables prepared by Ramanathan and Dave (1957), the atmosphere is divided into 9 layers, each 6 km in thickness. These tables take into account only the primary scattered light (P) received at the ground from the zenith sky; therefore, these authors have provided a subsidiary table giving the corrections which have to be applied to the observed readings of log I/I' to correct for multiple scattering in order to convert them to curves of primary scattering only, (log P/P'); (*see* Ramanathan and Dave for details). The corrections applicable to the Umkehr curves are given in Table 1.

In Fig. 1 the circles represent the *observed* points after corrections and the crosses represent points *calculated* in the manner described by Ramanathan and Dave (1957).

In calculating the vertical distribution of ozone, the observations at a zenith angle of the sun equal to 70° was taken as standard; the vertical distribution of ozone was determined by trial and error so as to give the best fit between the observed and calculated values of log (P/P') at 80°, 84°, 86·5°, 88° and 90°. In all these calculations Vigroux's absorption coefficients of ozone were used.

Table 2 gives the results of the distribution thus obtained in successive 6-km layers from the ground upto 54 km.

The variations from day-to-day are small.

Fig. 2 shows the block diagram of the vertical distribution of ozone obtained on 27 March and 6 April 1961, with ozone amounts 0·237 cm and 0·262 cm respectively.

Fig. 3 is an ozonogram showing the vertical distribution of ozone on 27 March, 5 April and 8 April 1961 obtained by the Umkehr method. There was an increase in ozone amount from 0·237 cm to 0·261 cm between 27 March and 5 April. The temperature diagram on the right shows that there was also a rise of temperature above 200 mb between the same two dates.

3. Surface ozone

The chemical method of Ehmert (1952) for determining surface ozone is based on the well known oxidation reaction of ozone with potassium iodide (KI). A known quantity of air, containing the ozone whose quantity is to be determined, is passed through a 2 per cent solution of potassium iodide (KI). The iodine liberated in the oxidation reacts with $Na_2S_2O_3$, a few micrograms of which are added to the 2 per cent solution of KI. The difference in the amounts of $Na_2S_2O_3$ in the two solutions, one through which air has been bubbled and the other a control, is measured by an electro-chemical method. This difference measures the amount of ozone contained in the known quantity of air bubbled through the solution.

Table 3 gives the results of the measurements of ozone concentration at ground level made by this method.

Dr. P. R. Pisharoty of the Institute of Tropical Meteorology, Poona has made the following comments on the upper wind circulation of the period 28 March to 5 April 1961.

"One remarkable feature during the epoch 28 March to 5 April, was the southward shift of the westerly maximum of upper tropospheric winds (noticeable at 12 km) to lat. 20°N or even south of it. For example, on 30 March, winds at Nagpur at 12 and 14 km were 100 knots, while at Delhi at the same levels they were about 50 knots. The total ozone amount over Delhi was a maximum on 30 and 31 March (0·269 and 0·289 atm. cm). The vertical circulations at 12–15 km associated with this jet maximum prevailing in this epoch, could have increased the tropospheric ozone content. We can take the tropospheric ozone to be well mixed and having a life of a few days. Perhaps the cloudiness and rain features were also associated with the southward shift of the westerly jet maximum".

From our observations it would appear that the ozone amount in the highest two layers 42-48 and 48–54 km is much larger than usual in these latitudes; this is worth investigating further. A comparison of the vertical distribution of ozone by the Umkehr method and the more direct ozone sonde technique will be made later.

TABLE 1

Corrections to the observed readings of log I/I' to obtain log (P/P')

Zenith	60°	70°	75°	80°	84°	86°·5	88°	90°
Corrections to be subtracted	0	1·0	2·0	4·5	6·0	6·0	6·0	6·0

TABLE 2

Date	Total ozone (cm)	Distribution of ozone in successive 6-km layers (10^{-3} cm/km)									Remarks concerning weather and sky
		0 to 6	6 to 12	12 to 18	18 to 24	24 to 30	30 to 36	36 to 42	42 to 48	48 to 54	
14-3-61	0·244	1·3	1·9	4·0	7·3	13·3	6·9	3·7	1·3	0·9	Hazy
20-3-61	0·254	1·3	2·7	4·1	7·3	13·4	7·3	4·0	1·2	0·9	Windy, *Ci* 3/8
22-3-61	0·254	1·3	2·7	4·1	6·7	16·0	6·4	2·9	1·2	0·9	Hazy
24-3-61	0·251	1·3	2·7	3·3	5·3	16·4	7·3	3·3	1·3	0·9	Thick *Ci* over entire sky
26-3-61	0·254	1·3	2·7	4·1	5·3	15·3	7·3	4·0	1·3	0·9	Hazy
27-3-61	0·237	1·3	2·7	4·2	6·4	14·0	7·3	2·7	0·5	0·4	Overcast at 0800 hrs
30-3-61	0·251	1·3	2·3	3·3	6·0	15·7	7·3	4·0	1·2	0·9	Hazy, afternoon rain
2-4-61	0·259	1·3	2·7	4·0	6·7	16·2	6·7	3·6	1·1	0·9	(*Ci*, *Cu*) 4/8
5-4-61	0·261	1·3	2·7	4·0	8·6	16·1	6·0	2·9	1·1	0·8	Rain
6-4-61	0·262	1·3	2·7	4·0	8·2	14·9	6·7	4·0	1·1	0·9	Hazy
8-4-61	0·246	1·3	1·7	2·7	4·7	13·4	10·6	4·0	1·3	0·9	*Cu* 3/8

TABLE 3

Date	Time (IST)	O_3 (micro-gram/m³)	O_3 (10^{-3} cm/km)	Weather remarks	Date	Time (IST)	O_3 (micro-gram/m³)	O_3 (10^{-3} cm/km)	Weather remarks
23-3-61	1000	22·7	1·1	Hazy	30-3-61	0830	26·1	1·2	Afternoon rain
24-3-61	0800	28·4	1·3	Thick *Ci*	1-4-61	0800	33·1	1·5	Rain on 31st night
25-3-61	0800	35·9	1·7	Rain	4-4-61	0800	59·1	2·8	Overcast
26-3-61	0800	30·2	1·4	Hazy	5-4-61	1000	52·0	2·4	Heavy rain
27-3-61	0800	33·1	1·5	Overcast	6-4-61	0800	70·9	3·3	Hazy
29-3-61	0800	47·3	2·2	,,	7-4-61	0800	73·2	3·4	Rain

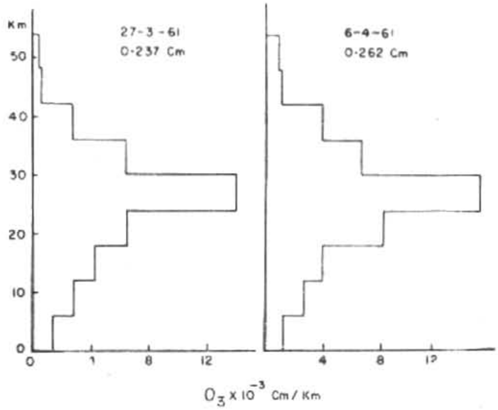

Fig. 2. Block diagram showing vertical distribution of ozone over Hyderabad on 27 March 1961 (0·237 cm) and 6 April 1961 (0·262 cm)

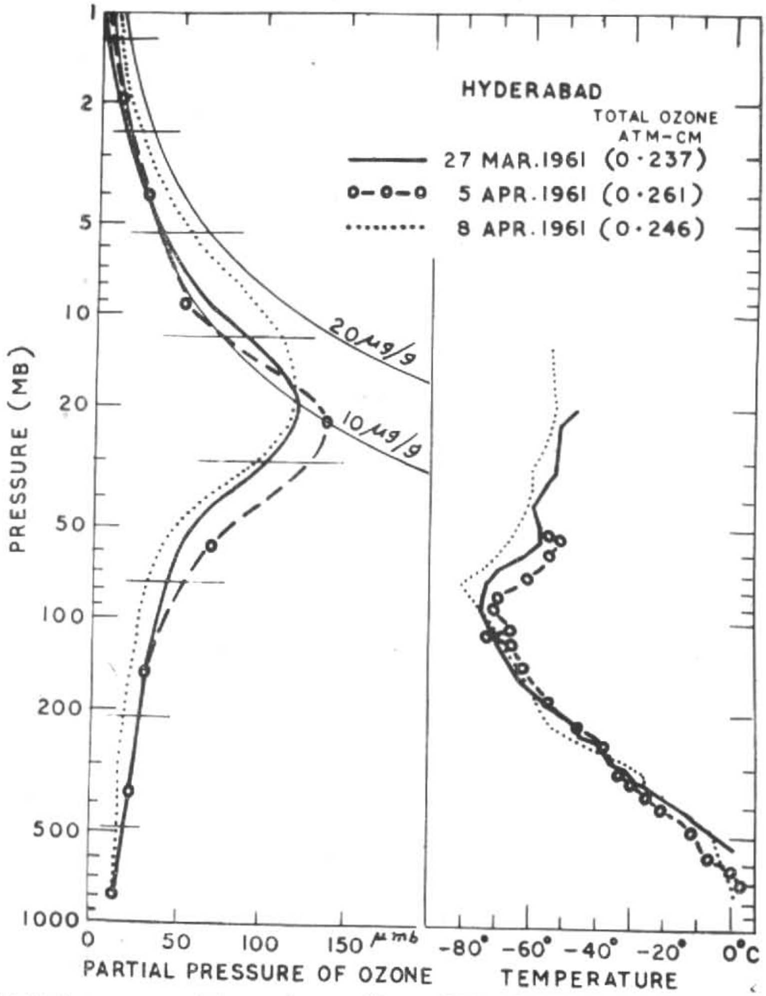

Fig. 3. Ozonogram and temperature profiles on 27 March and 5 and 8 April 1961

4. Acknowledgements

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