Some Results of Ozone Measurements during Indo-USSR Ozone Campaign 1987

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The data collected during the intensive observation period of the second phase of Indo-USSR Ozone Campaign conducted at the TERLS, Trivandrum, in December 1987 have been utilized to study various interesting features of ozone variations over India. The effect of the weather systems including western disturbances on the total ozone and vertical distribution of ozone has been studied. A comparison of vertical ozone profiles obtained by Umkehr method and ozonesonde at New Delhi and Pune has also been made. Surface ozone measurements recorded at the six Indian network stations have been analyzed.

1 Introduction

The ozone layer in the middle atmosphere absorbs the ultraviolet rays from the Sun and protects the Earth from the harmful effects. It also has a great influence on the stratospheric temperature and winds which are responsible for controlling the general atmospheric circulation and climate. In view of the important role played by atmospheric ozone, accurate measurements of ozone using ground-based, balloon-borne and rocket-borne instruments are very essential for effective ozone monitoring. For this purpose, the first phase of Indo-USSR ozone campaign was organized at TERLS, Thumba, in 1983 using the different types of rocket-borne ozone instrumentation by the participants as a part of the Indian Middle Atmosphere Programme (IMAP). As a continuation, a Phase II ozone campaign was conducted during Nov.-Dec. 1987 at Thumba. This campaign was necessitated as a result of certain discrepancies observed in the measurements of day and night rocket ozone sensors of India and USSR, so that a comparison of these sensors as well as evolving uniform scales for vertical ozone measurements during day and night become possible.

The India Meteorological Department (IMD) participated in the ground-based and balloon-borne ozone measurements in the Phase II campaign. During Nov.-Dec. 1987, uninterrupted and augmented surface ozone, total ozone measurements and long Umkehr observations for vertical ozone distribution from the network stations were organized. In addition to the routine ozonesonde observations, high altitude balloon ozonesonde ascents with increased frequency were organized from the Meteorological Centre, Trivandrum, as well as from New Delhi and Pune, during the campaign. Increased high altitude radiosonde/radiowind measurements were taken from three selected stations. These ozone measurements have provided sufficient data from the ground up to heights of more than 30 km to be used in conjunction with the rocket ozone measurements. In this paper, only the ground-based ozone measurements and the high altitude Indian balloon ozonesonde (electrochemical type) measurements carried out by IMD during the ozone campaign of Nov.-Dec. 1987 are discussed.

2 Ground-based and Balloon-borne Ozone Observational Programme

During the Phase II of Indo-USSR ozone campaign, the IMD organized the following augmented ozone observations during 15 Nov.-15 Dec. 1987.

(i) Daily observations of total ozone from Dobson stations with long Umkehr observations at New Delhi, Srinagar, Varanasi, Pune and Kodaikanal.
(ii) Weekly high altitude ozonesonde ascents from New Delhi, Pune and Trivandrum; additional ozonesonde ascents from Meteorological Centre, Trivandrum, during 3-9 Dec. 1987.
(iii) Continuous recording of surface ozone level at six stations from Srinagar, New Delhi, Pune, Nagpur, Trivandrum and Kodaikanal.
(iv) High altitude radiosonde/radiowind ascents from New Delhi, Bombay and Trivandrum.

3 Data for Analysis

The following data collected during Nov.-Dec. 1987 have been taken up for analysis.

(i) The observations which yielded a good data set of sixteen vertical ozone distribution profile up to stratospheric levels from the three stations including Trivandrum during the short span of time.

(ii) Total ozone observations and Umkehr observations recorded at five network stations.

(iii) Surface ozone data from three stations together with computed hourly mean values during the campaign period.

In addition, a study of the effect of weather systems, like western disturbances over north India and low pressure areas moving over the peninsular India during the campaign period, on the vertical ozone distribution (VOD) and total ozone to corroborate the earlier findings has been made.

4 Results and Discussion

4.1 Total Ozone Observations

The daily mean values of total ozone over Srinagar, Delhi, Varanasi, Pune and Kodaikanal, during 15 Nov.-15 Dec. 1987 are shown in Fig. 1. It shows that there is day-to-day variability of total ozone over the network stations from Srinagar to Kodaikanal. The variation is maximum (85 DU) in Srinagar and 41 DU in Delhi. However, Pune has shown minimum variation of 26 DU. The effect of moving western disturbances during Nov.-Dec. 1987 can be the cause for maximum variations of total ozone at Srinagar and Delhi. The maximum and minimum total ozone values at each of the five stations during the campaign period 15 Nov.-15 Dec. 1987 are shown in Table 1.

The mean hourly surface ozone values for New Delhi, Pune and Trivandrum during the campaign period are depicted in Fig. 2. The surface ozone recorded remains 20-25 μmbar between 0800 and 1800 hrs IST and remains practically negligible during other times of the day at all these three stations.

4.2 Comparison of Vertical Ozone Distribution (VOD) Profiles by Ozonesonde and Umkehr Observations

In the Phase II campaign, five ozone profiles which were obtained from IMD balloon ozonesondes and standard Umkehr observations from New Delhi and Pune as a part of augmented observations have been compared. Table 2 lists these VOD profiles for Pune and New Delhi. In general, the ozone maxima occurred at fifth layer (31.2/15.6 mbar) at a height between 23.7 and 28 km of Umkehr plot of New Delhi and Pune. The ozonesonde also showed maximum at the same range of pressure levels at both the stations, thus comparing well with the Umkehr measurements.

The ozone maxima shown by ozonesondes have been taken up for analysis.

Table 1 – Variation of Total Ozone during 15 Nov.-15 Dec. 1987

<table>
<thead>
<tr>
<th>Station</th>
<th>Maximum amount of total ozone (DU)</th>
<th>Minimum amount of total ozone (DU)</th>
<th>Variation (max-min) DU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Srinagar</td>
<td>310</td>
<td>225</td>
<td>85</td>
</tr>
<tr>
<td>New Delhi</td>
<td>274</td>
<td>233</td>
<td>41</td>
</tr>
<tr>
<td>Varanasi</td>
<td>257</td>
<td>224</td>
<td>33</td>
</tr>
<tr>
<td>Pune</td>
<td>240</td>
<td>214</td>
<td>26</td>
</tr>
<tr>
<td>Kodaikanal</td>
<td>263</td>
<td>233</td>
<td>30</td>
</tr>
</tbody>
</table>

Fig. 1 – Daily mean total ozone values for five Dobson network stations

Fig. 2 – Mean surface ozone values for New Delhi, Pune and Trivandrum
Table 2 – Comparison of Ozone Profiles Obtained from Umkehr and Balloon Soundings during Indo-USSR Campaign 1987

<table>
<thead>
<tr>
<th>Date</th>
<th>Station</th>
<th>Near ground</th>
<th>At tropopause</th>
<th>Near ozone maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Dec.</td>
<td>Pune</td>
<td>45/48</td>
<td>34</td>
<td>30/30</td>
</tr>
<tr>
<td>26 Nov.</td>
<td>New Delhi</td>
<td>72/46</td>
<td>24</td>
<td>−35/35</td>
</tr>
<tr>
<td>2 Dec.</td>
<td>New Delhi</td>
<td>25/42</td>
<td>23</td>
<td>15/30</td>
</tr>
<tr>
<td>9 Dec.</td>
<td>New Delhi</td>
<td>28/42</td>
<td>21.8</td>
<td>20/5</td>
</tr>
<tr>
<td>16 Dec.</td>
<td>New Delhi</td>
<td>18/28</td>
<td>20</td>
<td>25/10</td>
</tr>
</tbody>
</table>

*The maximum level of ozone is given in Umkehr/ozonesonde levels.

been always more than those shown by Umkehr method confirming earlier similar findings.

Similar comparison cannot be made for Trivandrum partly due to the spatial separation between Trivandrum (balloon station) and Kodaikanal (Dobson station) and more importantly due to non-availability of Dobson observations on many of the days from Kodaikanal due to bad weather conditions.

4.3 Effect of Weather Systems on the Total Ozone and Vertical Ozone Distribution (VOD) during Campaign Period

The earlier studies on the effect of weather systems on the VOD were made by Karandikar and Mani et al. Conspicuous day-to-day changes in ozone amounts were noticed and also sudden influx of ozone into the upper troposphere observed during passage of western disturbances over north India lowering the tropopause. During the post campaign period of 10-14 Dec. 1987 there had been one western disturbance moving across north Pakistan and Jammu and Kashmir causing considerable change in weather condition over Srinagar and adjoining areas. Fig. 1 shows the daily mean of total ozone of all the five stations. The total ozone variations over Delhi and Srinagar during the days of passage of the western disturbance are given in Table 3.

The above analysis shows that there is an increase of total ozone associated with a western disturbance at Srinagar and Delhi with the increase over Delhi occurring after a time lag of about 24 hr. The effect of increase is more over Srinagar than over Delhi. There is no effect of western disturbance on total ozone at other stations. These values, however, return to normal after the complete moving away of the western disturbance. These results only confirm the earlier findings.

5 Weather Pattern Analysis

A cyclonic circulation persisted over Maldives and adjoining Lakshadweep area and extended up to lower tropospheric levels between 25 and 28 Nov. 1987. There was a cyclonic circulation over southwest Bay and adjoining south Tamil Nadu and Sri Lanka extending up to lower tropospheric levels during the same time. Both of these systems became unimportant on 29 Nov. 1987.

A low pressure area moved from Andaman Sea and persisted with associated circulation extending up to lower tropospheric levels between 30 Nov. 1987 and 2 Dec. 1987. The circulation strengthened up to mid-tropospheric levels between 3 and 6 Dec. 1987 and the well marked low pressure area moved into Tamil Nadu coast and progressed westwards to emerge into the Arabian Sea. Thus, lower level tropospheric convergence in varying degrees persisted around Trivandrum during campaign period of 30 Nov.-5 Dec. 1987. Due to this low pressure system, there has been rain or thunderstorm activity at various places in Kerala including Trivandrum. But the
most severe and notable feature was on 3 Dec. 1987 when Trivandrum and its neighbourhood experienced very severe thunderstorm activity with heavy showers for about 3 hr between 1945 and 2230 hrs IST.

5.1 Analysis of Trivandrum Balloon Ozonesonde Data

Fig. 3(a) shows the vertical distribution of ozone and Fig. 3(b) the vertical distribution of temperature observed by seven ozonesonde ascents taken at Trivandrum during 26 Nov.-16 Dec. 1987. Fig. 4 shows the variation of maximum ozone partial pressure, atmospheric pressure and the ambient temperature at maximum ozone level in respect of the seven ascents. The ascent-to-ascent analysis and the results are given below.

(i) Ascent 1-2: The maximum ozone partial pressure increases and temperature and height of maximum ozone level decrease.

(ii) Ascent 2-3: The maximum partial pressure (PP_max) decreases and height of this level decreases slightly but temperature increases by about 8°C.

(iii) Ascent 3-4: PP_max falls slightly, height increases slightly and temperature decreases slightly.

(iv) Ascent 4-5: PP_max falls slightly, and height and temperature increase.

(v) Ascent 5-6: PP_max increases, and height and temperature increase.

(vi) Ascent 6-7: PP_max decreases, and height and temperature also decrease.

5.2 Variation of Ozone and Temperature at Constant Pressure Levels

The variation of ozone partial pressure and air temperature at 50, 30, 20, and 15 mbar levels are shown in Fig. 5 in respect of the seven ozone-
sonde ascents taken at Trivandrum. Some of the salient features are given below.

(i) At 50 mbar level, from ascent 5 to 6, there was an increase of ozone partial pressure by a factor of 1.1, whereas the temperature decreased by about 1°C. From ascent 1 to 2, there was an increase of the ozone partial pressure by a factor 1.2, but there was no change in the air temperature.

(ii) At 30 mbar level, from ascent 1 to 2, the ozone partial pressure had increased by a factor of 1.5, and the air temperature had decreased by about 4°C. From ascent 5 to 6 also, the ozone partial pressure had increased by a factor of 1.4, but the air temperature also showed an increase of about 1°C.

(iii) At 20 mbar level, from ascent 1 to 2, the ozone partial pressure had increased by a factor of 1.4 and temperature had decreased by nearly 3°C. From ascent 2 to 3, the air temperature had increased by about 6°C and the ozone partial pressure reduced by a factor of 0.9.

(iv) At 15 mbar level, from ascent 1 to 2, the ozone partial pressure increased by a factor of 1.2 and the temperature decreased by 2°C. From ascent 5 to 6 also, the ozone partial pressure had increased by a factor of 1.2 and the air temperature also increased by about 1.5°C. From ascent 6 to 7, the ozone partial pressure had decreased by a factor of 0.7 and the air temperature had also decreased by 5°C.

5.3 200 mbar Level Winds
An examination of 200 mbar winds during the campaign period shows that a feeble meridional flow from south was prevailing over extreme south peninsula and further north the flow being predominantly zonal. The wind had strengthened and by the evening of 3 Dec. 1987 the winds over extreme south peninsula attained a speed of 50 knots. Feeble meridional component, whenever present, was from south to north and hence there was no possibility of incursion of high latitude ozone rich air any day at 200 mbar level.

5.4 Vertical Time Section of Temperature over Trivandrum
The vertical time section of upper air temperature over Trivandrum for the period 15 Nov.-15 Dec. 1987 did not show any significant sudden warming or cooling at any of the tropospheric levels.

5.5 Vertical Time Section of Upper Wind and the Effect of Weather on Vertical Distribution of Ozone over Trivandrum
An examination of the vertical time section of winds over Trivandrum shows that the mid-tropospheric winds had strengthened between 26 Nov. and 3 Dec. 1987 and lower stratospheric winds also had strengthened considerably and the severe thunderstorm activity over Trivandrum had given rise to heavy rainfall by the evening of 3 Dec. 1987, the date of the second ozonesonde ascent under consideration. Due to veering of winds at 20 mbar level, ozone rich warm air advection from north could be the cause for increase in the ozone concentration. The cooling observed in the stratospheric air can be the result of ascent of cold air from lower stratospheric levels in association with vigorous development of severe thunderstorm in the evening of 3 Dec. 1987. The vertical temperature profile shows that the tropopause had been lowered and was cooler. Between the ascents on 3 Dec. and 5 Dec. 1987 the stratospheric winds had weakened and had become more zonal. That this backing of winds had decreased the ozone concentration and the warming that had been brought about by increased ozone concentration, has become evident at all levels from 50 to 15 mbar (Fig. 5). Though fall in ozone concentration continued in the ascents between 5 and 7 Dec. 1987, slight warming continued. Between the 5th and 6th ascents, mid-tropospheric winds as well as lower and mid-stratospheric wind speed substantially increased.

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References