INDIA

1. INTRODUCTION

India ratified the Vienna Convention for the protection of ozone layer on June 19, 1991 and the Montreal Protocol on Substances that Deplete the Ozone Layer on September 17, 1992. The India Country Programme was prepared in 1993 chalking out a strategy to phaseout production and consumption of Ozone Depleting Substances (ODS).

Atmospheric ozone monitoring started in India since 1928 when Dr. Royds made total ozone measurements in Kodaikanal with Dobson photoelectric ozone spectrograph as part of the first world-wide ozone measurements organized by Prof. G. M. B. Dobson. The first Dobson Spectrophotometer was acquired by India Meteorological Department (IMD) in 1940. The Indian ozone observational and research programme are as follows:

2. TOTAL OZONE OBSERVATIONS:

Total ozone measurements are being carried out at 6 stations by Indian Meteorological Department (IMD). Present network of six Dobson and two Brewer spectrophotometers are stationed at Sringagar, New Delhi, Varanasi, Pune and Kodaikanal.

At all stations routine measurements of total ozone are made (upto a maximum of six times per day) by trained personnel. Whenever, conditions permit, Umkehr observations are also made form these stations to compute the vertical distributions of ozone. Later, two Brewer Ozone Spectrophotometers were procured. One (#89) was installed at National Ozone Centre, IMD, New Delhi and other (#94) at Observatory Kodaikanal. It has an advantage over the Dobson Spectrophotometer because it is semiautomatic. Besides, it could also measure SO_2, NO_2 and UV-B.

2.1 Standardisation

The network instruments are calibrated against the National Standard at regular intervals. The National Standard is in turn, inter-compared against World standard in WMO organized International Intercomparisons. India participated in such comparisons held at Belsk (1974), Boulder (1977), Melbourne (1984) and Japan (1996). New Delhi is the National Ozone Centre for India and the Regional Ozone Centre for the Regional Association-II (Asia) of the World Meteorological Organization (WMO).

2.2 Publication of data

The total ozone data and Umkehr data (vertical profile of Ozone) are being regularly sent in WMO format to the World Ozone Data Centre (WO3DC) Canada, and are being regularly published by the Centre.

3. CURRENT TOTAL OZONE RESEARCH

3.1 Long term trend of Tropopause over the Indian region

Radiosonde observations were taken during the past 32 years at New Delhi (28^0N, 77^0E) and 26 years at Thiruvananathpuram (8^0N, 76^0E) and has been analyzed to examine the long-term trend of tropopause height (TPH) and tropopause temperature (TPT) at these two stations. From the result, it appears that TPH was increasing and TPT was decreasing over the years. The trend of change was not same throughout the period of study. Considering the whole period of data we find that the increase of TPH was in the range of +0.57 to +1.13 % decade and the decrease of

TPT was in the range of –0.53 to –0.94 % decade. Qualitatively this was explainable with the decreasing trend of ozone in the stratosphere. Results of analysis shows that long-term change in the tropopause characteristics is taking place over the India region. This change is not unidirectional throughout the period of study.

3.2 Ozone concentrations over India

Ozone observations were taken during the past several years by Dobson Spectorphotometers at Delhi, Varanasi, Pune and Kodaikanal have been analyzed to examine its long-term trend over Indian stations. An increasing trend of total ozone over the yeas has been noticed at all the places, except at Varanasi, where a decreasing trend has been found. The cause of these trends could be attributed, partly, to the trends of ozone in the troposphere. The results also indicate that there are certain changes in ozone levels at the Indian stations. These changes are less apparent in the long-term trend analysis of total ozone data, as the increase in tropospheric ozone has a compensating effect to the decrease in ozone at stratospheric levels.

4. VERTICAL OZONE DISTRIBUTION

The development of an Indian ozonesonde was taken up in 1963. The first successful sounding was carried out in September, 1964. The sondes were subsequently intercompared in WMO/IO_3C comparison held in West Germany in 1970 and 1980; in 1991 (Canada) and 1996(Germany). Since early 1970 fortnightly soundings are attempted at New Delhi, Pune, Thiruvanathapuram, Dakshin Gangotri and Maitri (Antarctica).

4.1 Current vertical Ozone Distribution Research:

4.1.1 Vertical distribution of ozone over the Indian Ocean (15^0 N-20^0S) during Second Field Phase INDOEX-1999.

The vertical distribution of ozone over the Indian Ocean was measured during the second field phase (FFP) of Indian Ocean experiment from 15^0N to 20^0S in February/March 1999. A pocket of low ozone (~10 ppbv) was observed near the surface in addition to high ozone concentration observed at 8-12 km within the region of 5-15^0S during both INDOEX FFP-98 and INDOEX IFP-99. However, the north-south gradient in ozone concentration and the layered structure at 5-8 km as observed in INDOEX FEP-98 are not prominent during INDOEX IFP-99.

East-west cross-section of ozone concentration in the troposphere along 20^0S and 15^0N may be characterized as the background value of pristine and continental air on the northern and southern side of the equator, respectively. Through back trajectory analysis indicates that flow of air masses is mostly form the Indian subcontinent as well as south-east Asian region, it is difficult to distinguish the degree of relative contribution of continental flow to ozone concentration over the Indian Ocean. The comparison between marine and continental ozone profiles suggests that the northern side of the Inter Tropical Convergence Zone (ITCZ) resembles the continental profiles as observed over the Indian subcontinent and African region, rather than east Asian region.

5. ALLIED PROGRAMME

Indian Middle Atmospheric Programme (IMAP), operating since 1982, has provided an umbrella for integrating all Indian efforts on ozone research. Rocket Programmes in collaboration with ex-USSR were stepped up during this period with payloads from physical Research Laboratory, Ahmedabad and the National Physical Laboratory at Delhi launched at Tumba. These, along with balloon and ground based measurements, have well characterized the ozonesphere over India.

Indo-Russian collaborative programme on variations in ozone and aerosol content in tropics/extratropical troposphere and stratosphere are being studied.

5.1 The Laser Hetrodyn System (LHS) and mm wave radiometer:

This system monitors the 10 micron ozone line in absorption mode against the Sun. The mm wave radiometer observes the 101 GHz ozone line in emission mode. This instrument has the advantage over LHS that it can be operated round the clock under all weather conditions as it does not require direct sun light. The line profiles in both the experiments are inverted to obtain the Ozone height distribution. The ozone height profiles over Delhi and Maitri have been generated for a limited period using these techniques.

6. SURFACE OZONE MEASUREMENTS

During the 70s, the electrochemical surface ozone measurement system was successfully developed. The system is successfully operating at New Delhi, Pune, Kodaikanal, Thiruvanathapruam, Nagpur, Srinagar, Dakshin Gangotri and Maitri.

7. UV-B MEASUREMENTS

Regular measurement of UV-B radiation by filter photometer were started in 1979 at Physical Research Laboratory, New Delhi. At present under Indian Middle Atmospheric Programme (IMAP) a chain of 7 stations have been established for routine measurement of global UV-B radiation at 280, 290, 300 and 310nm using narrow band interference filters at Shillong (IMD), Jodhpur (IMD), Pune University, Waltair Andhra University, Mysore University and Trivandrum (CESS).

7.1 UV- Biometer

The measurement of Minimum Erythermal dose in the UV-B range started at Delhi in 1995 January and is continuing.

7.2 UV Spectroradiometer

The spectral measurements in the UV-B range at ½ nm interval started in 1989 and is continuing. The UV network is likely to expand and coordinated with international programme.

8. INDIAN OZONE PROGRAMME OVER ANTARCTICA

Considering the importance of ozone measurements over Antarctica, an International Ozone Campaign had been organized during 1987. India participated in campaign and had set up observational facilities at Dakshin Gangotri (DG) (70^0.75 S, 11^0.75E) during the summer and winter expeditions of 1987. The programme started with UV-B radiation measurements and later on more sophisticated instrument like Laser Hetrodyne System (LHS) and Millimeter Wave radiometer were introduced. Regular ozone soundings from Maitri (Antarctica) (70^0 46'S, 11^0 45'E) are carried out with the Indian electrochemical ozone sonde.

The spectral measurement of UV-B started in 1987 and is continuing. Minimum Ecothermal dose measurement also started in 1993 to study the effect of vertical ozone profile. The National Physical Laboratory has established a millimeter-ground base instrument at Maitri, Antarctica for continuous ozone observation during the year under all weather condition.

9. MEASUREMENT OF MINOR CONSTITUENTS

Various greenhouse molecules such as Carbon Dioxide (CO_2), Methane (CH_4), Nitrus Oxide (NO_x) have also been measured regularly at National Physical Laboratory, New Delhi, Physical Research Laboratory, Ahmedabad and Banaras Hindu University, Varanasi.

10. FUTURE PLANS:

a) Continuous monitoring of ozone profile over the country.
b) Study on atmospheric chemistry in relation to ozone layer depletion and climate change.
c) To participate in the international intercomparisons of Dobson Spectrophotometer, Brewer Spectrophotometer and Ozone sonde.
d) To develop biological system to monitor UV-B.
e) To continue research on impact of UV-B on human health and eco-systems.
f) To develop climatic models to predict the climatic change over India.

11. REFERENCE

A large number of papers have been published in various journals. Most recent ones are:

- Recent changes observed in column ozone concentrations over India, MAUSAM, 51, 1 (January 2000), 69-74.
- Long-term Trend of Tropopause over New Delhi and Thiruvananthapuram, GEOPHYSICAL RESEARCH LETTERS, VOL. 27, NO. 15, PAGES 2181-2184, AUGUST 1, 2000.
- Further evidence of total ozone variation during the solar eclipse of 1995, JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 106, NO. D3, PAGES 3213-3218, FEBRUARY 16, 2001.
- Observations of vertical distribution of tropospheric ozone over Indian Ocean and its comparison with continental profiles during INDOEX FEP-1998 and IFP-1999, CURRENT SCIENCE (SUPPLEMENT), VOL.80, 10 APRIL, 2001

***