Twenty Second Indian Expedition to Antarctica, Scientific Report, 2008
Ministry of Earth Sciences, Technical Publication No. 20, pp 109-116

Ozone Hole during 2002 and 2003: A Comparison

S. L. Jain, B. C. Arya, Sachin D. Ghude, Ashok Kumar and V. B. Gupta*
Radio and Atmospheric Sciences Division
National Physical Laboratory, New Delhi-110012 (India)

*School of Future Studies and Planning, Devi Ahilya University, Indore,
M.P. (India)

ABSTRACT

Total column ozone has been measured using Microtop Sun photometer at Maitri (70° 45'S, 11° 44'E), Antarctica, during 21st and 22nd Indian Scientific Expedition to Antarctica. A comparison of TOC at Maitri over Schirmacher region of east Antarctica has been made to understand the behaviour of ozone hole in relation with stratospheric temperature. The observation showed relationship between the stratospheric temperature and TOC. The minimum values of TOC of about 185 DU and 126 DU were observed in the year 2002 and 2003 respectively during ozone hole period. The ozone hole values (less than 220 DU) during ozone hole period at Maitri was found out to be 20.7 % and 62.7 % in the year 2002 and 2003 respectively. Temporary sudden rise in TOC before the recovery period were also observed in both the years. In present communication the results obtained are discussed in detail.

Key **Words:** Ozone Hole, Antarctica, Polar Vortex, Planetary Waves.

INTRODUCTION

Ozone is one of the most important greenhouse gas in the atmosphere and in spite of its low concentration, a few ppmv in mixing ratio, it plays an important role not only in the chemistry of this region but also it affects dynamics and biological activity near the surface. The amount of ozone **over** any particular place depends not only on photochemical balance, **but also** on **the** stratospheric climate, **the** winds that transport the ozone (Hartmann, 1994). Ozone is also one of the most important constituents in the atmosphere and is the only greenhouse gas that strongly absorbs solar radiation at the ultraviolet end of the spectrum. As **a** green house gas, it traps the long wave radiation in 9.6 |im band and thus affects the energy budget of the earth - atmosphere system. Stratospheric ozone protects the Earth's surface from harmful solar ultraviolet radiation (especially UV-B) and plays an important role in controlling the temperature structure of the stratosphere by absorbing incoming solar ultraviolet radiation and outgoing terrestrial long-wave radiation.

Most of the ozone is produced over the tropics and transported to higher latitude by the general circulation of the stratosphere. The Brewer-Dobson circulation transports ozone out of its tropical source region into the polar region. Based on both satellite and ground base measurement, Harris (1997) reported that at mid latitudes of northern and southern hemisphere the total ozone column is decreasing. WMO (1995) reported 4.6 % per decade decrease in the total ozone column during 1979 to 1994.

The area covered by extremely low values less than about 220 DU of column ozone is generally defined as ozone hole area. The factor involved in the formation of ozone hole during Antarctic spring is catalytic depletion of ozone due to heterogeneous chemical reaction (Cadle et al., 1975) on the surface of the ice particle (Polar stratospheric clouds), which transforms comparatively inert $C10_x$, HC1 and NO_x (Farman et al, 1985) into active forms of chlorine compound. However, it has now established that the development of the Antarctic ozone hole is strongly influenced by photochemical balance (Crutzen et al., 1986), the winds that transport the ozone and meteorological conditions in the stratosphere (Hartmann 1994).

In view of the above a hand held microprocessor based sun photometer, i*.e., MICROTOP-H, has been used to measure total ozone at Maitri, Indian Antarctica research station during the years 2002 and 2003. The observations were taken throughout the expedition on hourly basis during clear sunny days. In the present communication, the experimental setup and results obtained are discussed in detail.

EXPERIMENTAL SETUP

The MICROTOP-II is a five-channel hand held microprocessor based sun photometer with a full field of view of 2.5°. The instrument has five optical collimators aligned to aim in the same direction. A narrow-band interference filter and a photodiode suitable for the particular wavelength range are fitted with every channel. All the channels face directly the solar disc simultaneously when the image of the sun is centered at the cross hairs of the sun target. When the radiation captured by the collimators falls onto the photodiodes, it produces an electrical current proportional to the received radiant power, which is amplified and converted into digital form in a high resolution A/D converter. Signals are processed in a series of 20 conversions per second. Out of the five channels at 300, 305, 312, 940 and 1020 nm, the first three filter channels are used to derive atmospheric total ozone column and other two for water vapour (Jain, 2001). In the present communication the results obtained are discussed in detail.

RESULTS AND DISCUSSION

A comparison in the variation of Total Ozone Column (TOC) over Maitri during the year 2002 and 2003 is shown in Fig. 1. The gape in the figure is due to non-availability of data during polar night. The instrument MICROTOP-II can be used to get data only for daylight-viewing conditions of solar zenith angle (SZA) less than 67 degrees, so total ozone data are not available at polar latitudes during winter darkness. Total ozone measured at Maitri during January to December (expect during polar night period) is depicted in Fig. 1, which showed the prevalence of ozone hole during 2002 and 2003.

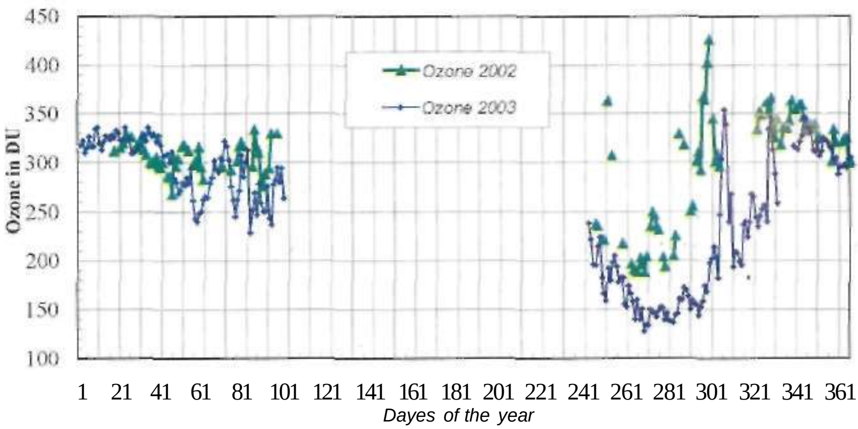

Fig. 1: Comparison of total column ozone during the year 2002 and 2003 at Maitri, Antarctica

The minimum TOC observed at Maitri during 2002 was 185 DU, while it was 126 DU in 2003. The ozone hole values (< 220 DU) during ozone hole periods were found out to be 20.7% in the year 2002 and 62.7% in the year 2003. TOC frequency distribution during observed ozone hole period (August to December) in both the years is depicted in Table 1. Ozone values less than 135 DU, less than 150 DU and between 150 -220 DU were observed 0%, 0% and 20.7% respectively in the year 2002, while 2.8%, 15% and 47 8% respectively in the year 2003. This observation revealed that the ozone hole was quite deeper and ozone depletion inside the vortex over Maitri during ozone hole period in 2003 was larger than the year 2002.

Table 1 Frequency distribution of ozone values during ozone hole period (August to December) observed over the Maitri

Year	Days of observation	Values less than 135 DU	Values less than 150DU	Values between 150-220 DU	Above 220 DU	Days of ozone hole in %
2002	140	0 %	0 %	29 (20.7 %)	111	20.7
2003	138	4 (2.8 %)	22 (15 %)	66 (47.8 %)	66	62.7

Fig. 2 shows the monthly averaged temperature anomalies at 50hPa for the latitudinal region 90° S - 65° S. The figure is taken from the NO A A/ National Weather Center website. Negative temperature anomaly **was** observed before and during ozone hole period but showed warming in early November 2003. Monthly averaged upper air temperature at 50hPa over nearby station; Novolazarevskaja (70.8°S, 11.8°E, 119 m) during 2002 and 2003 is depicted in Fig. 3. The data is available on the website of SCAR (Scientific Committee on Antarctic Research) under READER (Reference Antarctic Data for Environmental Research) project (http:// www.antarctica.ac.uk/met/READER). The monthly averaged minimum temperatures recorded were -88.6° C (50 hPa) in 2003. This indicates that stratospheric temperatures in the winter-spring 2003 were much lower than the 2002 and coincided with a much stronger ozone hole in 2003. Although the ozone hole in 2003 over Maitri shows comparatively higher ozone loss, wanner meteorological condition of about -45° C developed in early November, as seen in Figs 2 and 3, closed the further destruction of ozone.

It is now well established that the development of the Antarctic ozone hole is influenced strongly by photochemical balance, the winds that transport the ozone and meteorological conditions in the stratosphere (Hartmann 1994). The low temperature during winter time over Antarctica leads to formation of polar stratospheric clouds (PSCs) (Manney et al. 1996) and polar vortex. This vortex limits the exchange of air between its interior and its exterior and leads to extremely low temperatures. PSCs provide surfaces where, in the presence of ice particles and sunlight, the production of reactive chlorine and heterogeneous reactions is enhanced, converting less reactive molecules

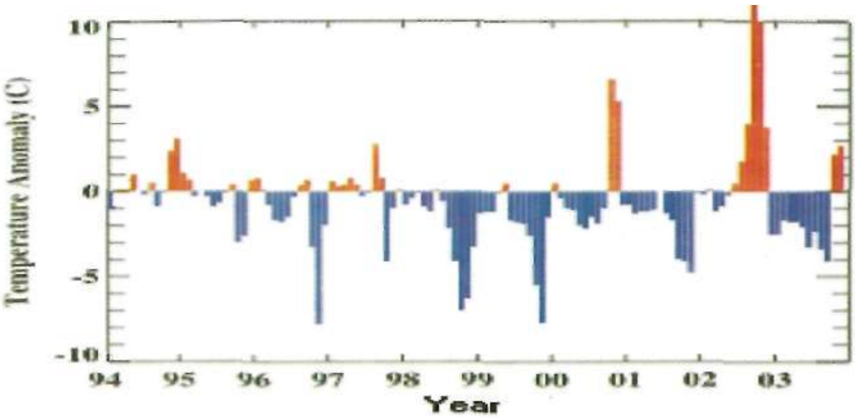

Fig. 2: Monthly averaged temperature anomaly (Degree C) at 50 hPa for the latitude band of 65°S - 90°S

into much more reactive forms that readily destroy ozone. A major warming in the stratosphere is a wintertime dynamic phenomenon that indicates an unstable atmospheric polar vortex and results in rapid and substantial transport of air between the low and high latitudes. The amount of exchange between vortex and mid-latitude air influences the amount of chemical processing of ozone and, hence, total ozone (TOZ) in the column (Grainger and Karoly 2003). Ozone column density, therefore, varies with temperature in the lower stratosphere and movement of air in the lower stratosphere. It has now been established that temperatures in the lower stratosphere are coupled closely to ozone through dynamics and photochemistry and also very dependent on the movement of the polar vortex and planetary wave conditions. Planetary waves displace air north and south, originate in the troposphere and propagate upward, transferring their energy to the stratosphere and warming it. These vast pressure waves influence ozone destruction in several ways and can have a relevant impact on the size and stability of the Antarctic vortex. If the strength of these waves is high enough then this forces the surrounding warm, ozone-rich air mass into the cold air of the polar vortex and a sudden warming of the stratosphere take place, called sudden stratospheric warming (SSW).

Varotsos (2004) found that anomalous strong tropospheric transport of air from the sub-tropic to the polar region could be direct cause of sudden stratospheric warming (SSW). This indicate that the magnitude of planetary waves and the heat flux transport toward the South Pole and upward transport of the wave energy was unprecedented in the year 2002 in southern hemisphere (SH), and in the year 2003, these planetary waves of air pressure was unusually weak while the ozone hole was forming during August and early September. As can be seen from Figure 3, the stratosphere was relatively warm during winter-spring during 2002 and much colder during 2003. This

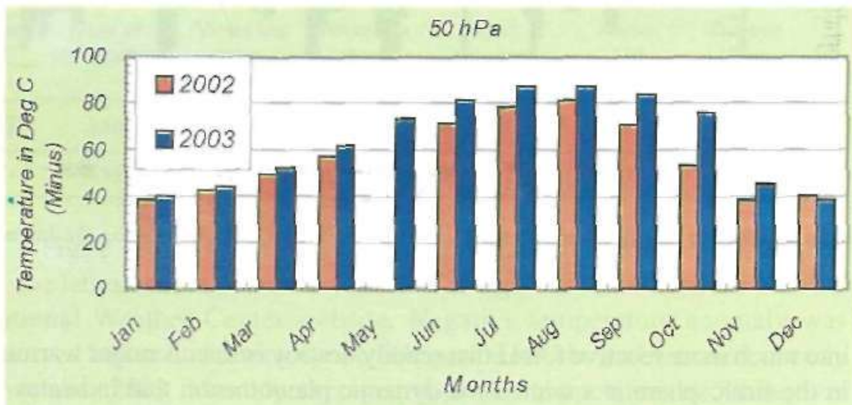

Fig. 3: Monthly averaged upper air temperature at 50hPa at Novolazarevskaja (70.8S11.8E, 119 m), Antarctica

colder temperature lead to more stable polar vortex and large loss of ozone concentration compared to 2002.

Furthermore, an interesting signature of temporary sudden rise in TOC before the recovery period (day no 300-315) was also observed. It has also been observed that the final recovery of ozone hole and temporary sudden rise in TOC are the even separated by a time interval of 15 to 30 days. The temporary sudden rise in ozone values was observed 362 DU and 351 DU in the year 2002 and 2003 respectively and need further critical analysis.

CONCLUSION

A comparison of ozone hole during 2002 and 2003 over Maitri Antarctica has been made in relation to stratosphere temperature. The observation showed direct relationship between the stratospheric temperature and TOC. The minimum values of TOC of 185 DU and 126 DU were observed in the year 2002 and 2003 respectively during ozone hole period. The ozone hole duration was observed 62.7 % in 2003 while it was 20.7 % in 2002 over Maitri station. However, although the stratosphere was much cool and extensive ozone depletion was again observed in 2003 as compared to 2002, the steady increase in total ozone values from late October coincides with warming occurred in early November.

ACKNOWLEDGEMENT

We thank to the Director, NPL and Head, RASD, for their encouragement during the progress of the work. Thanks are also due to the NCAOR (Department of Ocean Development) and CSIR for logistic and financial assistance. Thanks are also due to Leader, Novo Station, for providing ozone data. Thanks to National Space Science Data Center, NASA, Goddard Space Flight, USA, for receiving TOMS data from their website (http:// www.science.nasa.gov/.). We are also thankful to Indian Metrological Department for providing surface temperature data. Thanks also to NOAA/ National Weather Center website for availing figure of Monthly averaged temperature anomaly at 50 hPa for the latitude band of 65° S - 90° S. Finally, thanks to SCAR (Scientific Committee on Antarctic Research) for downloading data from their website under READER project. The our sincere gratitudes to the leaders of the expeditions and team members for their time to time help and cooperation.

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