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Measurement of ozone at Maitri, Antarctica

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Abstract

The solar radiation at five wavelengths 300 nm, 305 nm 312nm, 940 nm and 1020 nm using narror band (2.5 nm FWHM) filters has been measured using a microprocessor based sun photometer from Jan. 1997 to Feb. 1998 on hourly basis on all clear days at Maitri during Sixteenth Indian Scientific Antarctic expedition. The total column ozone has been estimated from these measurements. Very low ozone values have been observed during Antarctic spring, which confirmed the continuity of ozone hole phenomenon. It has also been found that ozone values are high during Antarctic summer while low during spring.

1. Introduction

Ozone in the stratosphere is very important for the survival of life on the earth as it protects us from harmful ultraviolet radiation coming from the sun. Ozone in the troposphere also acts as a greenhouse gas, trapping the long wave radiation and thus affecting the energy budget of the earth-atmospheric system. The reporting of ozone hole in particular by Farman et al. (1985) and ozone depletion in general by Johnston et. al. (1971) has generated an unprecedented surge of interest in the scientific community in monitoring of ozone in the atmosphere. The chloro-fioro carbons are the main culprits of ozone depletion in the stratosphere and ozone hole phenomenon over Antarctica.

Ozone is one of the most important trace gases in the atmosphere, and it is responsible for influencing many critical chemical and radiative processes. Ozone contributes to the formation of the hydroxyl radical (OH) which is central to most chemical reactions in lower atmosphere, and it absors UV, visible, and infrared radiation which affects the energy budget and atmospheric temperature. In addition, ozone can be used as a tracer of the atmospheric pollution and stratosphere-troposphere exchange. At elevated concentratins, ozone in troposphere can also produce detrimental biological and human health effects.

In Polar Regions high-speed wind jet circulates around the poles and serves as a barrier to air exchange between Polar Regions and mid latitudes which forms polar vortex. Very low temperature during winter leads to the formation of polar stratospheric clouds (PSCs). The hetergogeneous chemical reactions takes place on the surface of PSC's which is responsible for the ozone hole phenomenon (Manney et al., 1996). Ozone has been found to be strongly affected by the dynamical behavior of the polar vortex (Carswell et at. 1996). Ozone depletion events were detected at latitudes as low as 33 S in the south of Argentina and Chile by Perez et al. (1996) by a network of ground stations located in Argentina and Chile between latitudes 53 S and 33 S during the spring of 1993, 1994 and 1995. Orce et al (1997) have shown that the ozone hole was over south America extending to about 38 degree S for at least a week during October and about two weeks during November-December of the years of 1994-95.

In view of the above a highly sophisicated and hand held microprocessor based sun photometer, MICROTOP-II, has been used to measure total ozone, water vapour, optical depth etc. The instrument was taken to Maitri (Antarctica) in 16th Indian Scientific Antarctic Expedition-1996-98. The observaations were taken throughout the expedition on hourly basis during clear sunny days. In the present communication working principle of instrument and the results obtained are discussed in detail.

2. Experimental set-up

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 centrered 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 were used to derive atmospheric total ozone column and rest of the two for water vapour which is discussed elsewhere.

3. Theory

Ozone absorbs shorter wavelengths of ultraviolet radiation much more than longer wavelength. This means that the amount of ozone between the observer and the sun is proportional to the ratio of two wavelengths of the Sun's ultraviolet radiation. Microtop uses that relationship to derive the Total Ozone Column from measurements of three wavelengths in the UV region. The measurement at an additional 3rd wavelength enables a correction for particulate scattering and stray light.

The Lambert-Beer law, when applied to ozone absorption and Rayleigh scattering by the atmosphere, gives the equation

$$I = I_o e^{-a\mu\Omega - m\beta P / P_o}$$

Io is the intensity of light of a particular wavelength before it passes through the

atmosphere, I, the intensity received, is the amount of ozone, a is the ozone absorption coefficient, u the ratio of the actual and vertical path lengths through the ozone layer, P is the pressure of the atmosphere in mb, Po is standard pressure= 1013.25 mb,m is air mass which is ratio of the actual and vertical path lengths of the radiation through the entire atmosphere to the detector and B is Rayleigh scattering coefficient. Here paraticulate scattering is ignored, as the worst haze conditions do not affect ozone measurements by more that a few percent and much less under conditions (Basher et al. 1979).
Expressions for m and u are (Kohmyr et al. 1989),

$$m=\sec x - 0.0018167.(\sec x -1) - 0.002875.(\sec x-1)^2 - 0.0008083.(\sec x-1)^3$$

$$\mu = \frac{R+h}{[(R+h)^2 - (R+r)^2 \sin^2 X]^{1/2}}$$

or

$$\mu = \frac{1}{1 - \nu.\sin^2 x}$$

Where v is a geometric factor for the height of the ozone layer and is given by

$$\nu = \frac{(R+r)^2}{(R+h)^2}$$

R is mean earth radius (6371 km), r height of ozone station above sea level in km, *x* is solar zenith angle and h is height of ozone layer above sea level approximately as:

$$h[km] = 26 - 0.1 * latitude\ [°]$$

The expression for the ozone value derived for any channel pair (say 1 and 2) is

$$\Omega(DU) = \frac{1000*[L_{12} - \ln(\frac{I1}{I2}) - \beta_{12} * m \frac{P}{Po}]}{\alpha_{12} * \mu}$$

Where

$$\alpha_{12} = (\alpha_1 - \alpha_2) \qquad \beta_{12} = (\beta_1 - \beta_2)$$

are the differences in the ozone and scattering coefficients respectively for respective channnles 1 and 2 and

$$L_{12} = (L_1 - L_2) = \ln(I_{01} / I_{02})$$

is the combined extraterrestrial constant which corresponds to measurement of the incidence radiation above the earth's atmosphere. It is obtained by extrapolating a plot of In (I/I) vs μ (Langley plot).

4. Results and Discussion

The variation of total ozone column during the observational time from Jan 4, 1997 to Feb. 4, 1998 is shown in Fig. 1. At Maitri maximum ozone up to 320 DU has been recorded in the months of January and February, After February ozone column density started decreasing as shown in the figure. The gap in the figure is due to non availability of sun during polar night. Minimum measured ozone value in the first week of October was about 135 DU, which confirms the continuity of ozone hole phenomenon at Maitri. Ozone hole period was observed during last two weeks of September and first two weeks of October. After spring ozone value again started recovering and becomes normal in December and January. It was observed that total ozone column is very much dependent on the planetary wave conditions. Exceptionally high value of total ozone observed on

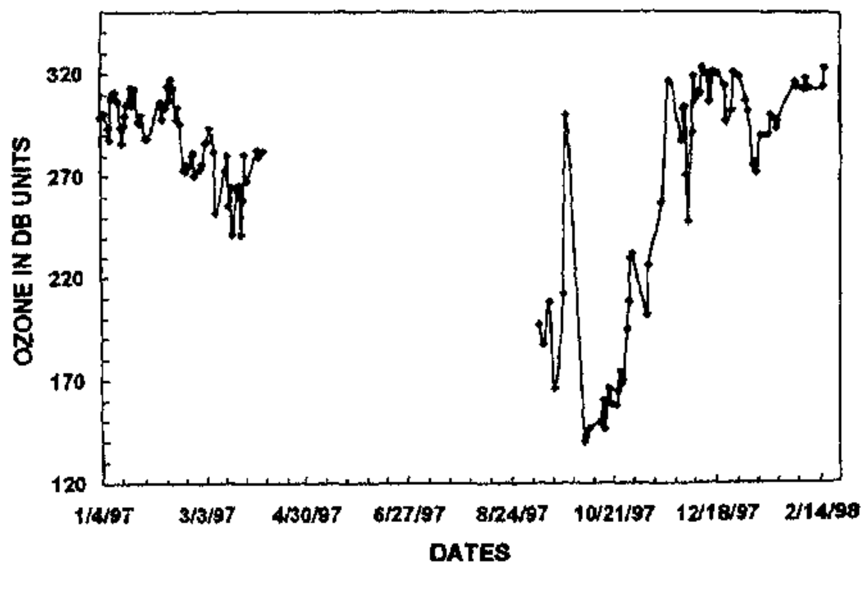

Fig. 1 : Ozone variation at Maitri during J 997-98

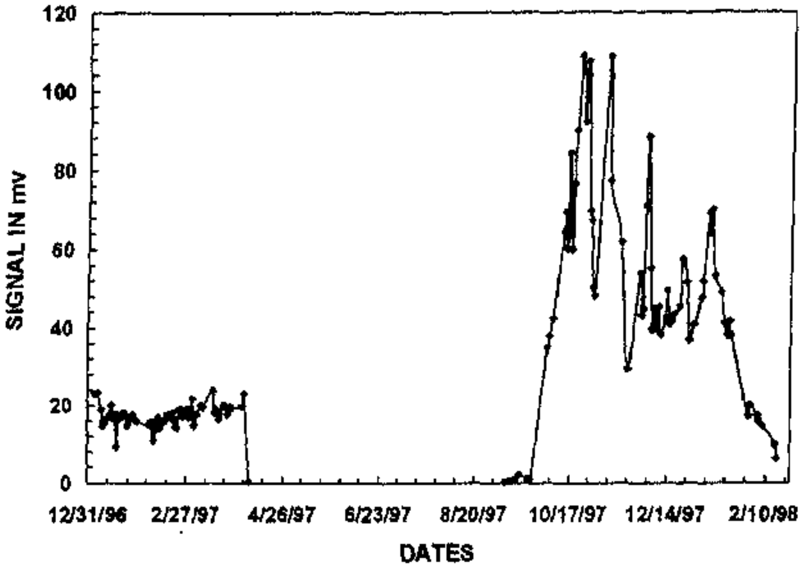

Fig. 2 : UV-300 at Maitri

September 24 as shown in Fig. I during ozone hole period may be attributed to the planetary wave phenomenon as Maitri, the Indian Antarctic Station is located on the fringe of the vortex. As suggested by Schoeberl et al. (1988), the amount of exchange between vortex and mid latitude air influences the amount of chemical processing of ozone and hence total ozone column. Ozone column density varies with movement of air in lower stratosphere. E.K.Brinksma et al. (1998) have shown that advection of ozone poor air in two altitude regions caused recorded low ozone values over Lauder station, New Zealand during the 1997 winter. The ozone column density measured over Lauder between 1987 and 1996 was 348(±28) DU whereas in August 10, 1997 ozone column density was unusually low with a minimum value of 222 DU (E.J Brinksma et al., 1998).

The variation of ultra-violet solar radiation at 300 nm during the period of observation at Maitri is shown in Fig.2. From the figures 1 and 2 it is found that UV radiation and ozone are anti-co-related i.e UV radiation are at maximum when the ozone is minimum

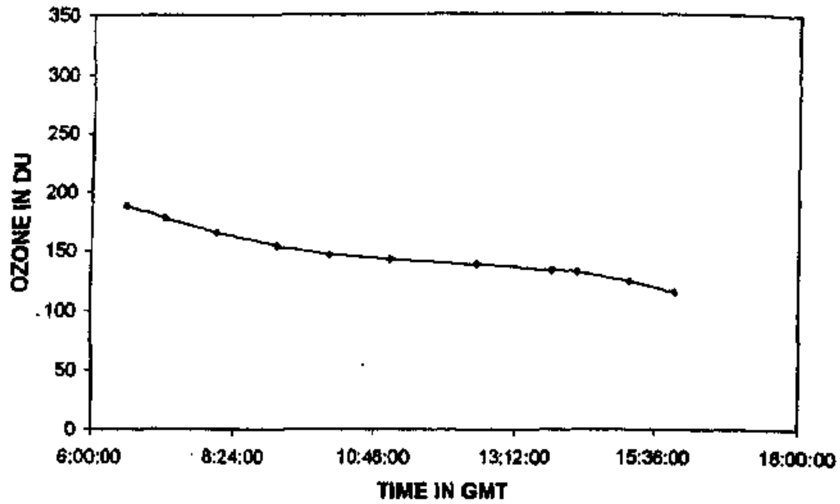

Fig. 3 : Diurnal variation of ozone on 05.10.1997

Diurnal variation of ozone at Maitri during ozone hole period and during Antarctic summer are shown in Figs. 3 and 4 respectively. During ozone hole period, total ozone column was found to be slightly decreasing from morning to evening whereas in summer it was maximum during noon.

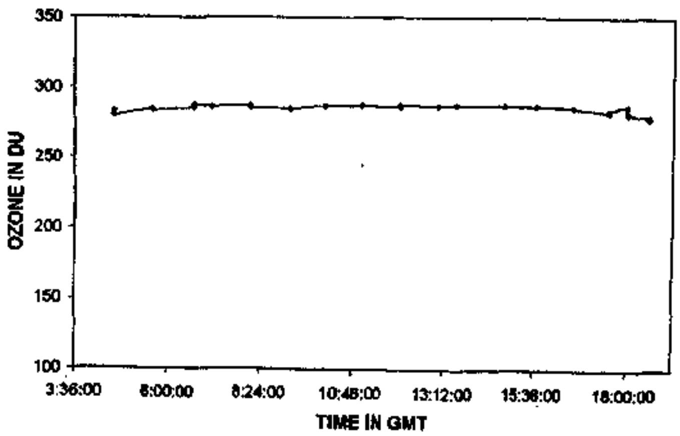

Fig. 4 : Diurnal variation of ozone on 09.01.1997

The sun photometer has proved to be an important tool to measure total ozone, water vapour, aerosol optical depth etc. The observations are being continued at Maitri to understand physics, chemistry and radiation budget in the atmosphere.

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