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Study of Ozone Hole Over Maitri, Antarctica During 2002

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Abstract

Total column ozone has been measured using Microtop Sunphotometer at Maitri (70° 45'S, 11° 44'E), Antarctica, during 21st Indian Antarctic Scientific Expedition (2002-2003). The Maitri observations were also compared with TOMs data as well as nearby Russian station data and were found to be in good agreement. The water vapor has also been measured on the way from Goa, India (15.24° N, 73.42° E) to Maitri, Antarctica (70.44° S, 11.45° E) on the ship Magdalena Oldendroff. The ozone hole during spring of 2002 over Maitri did something unusual reflecting the unusual behavior of the planetary waves in the Southern Hemisphere, which confirmed the roll of capricious weather in the opining and closing of ozone hole. The observation shows that the ozone hole in the year 2002 was not as deep as that of the previous years. The minimum value of total ozone of about 185 DU was observed in the last week of September during 2002 and exceptionally high values of about 420 DU were observed during the ozone hole period. The observation also reveals the early recovery of ozone hole during 2002 as compared to 1997.

Keywords: Ozone Hole, Polar Vortex, Planetary Waves.

Introduction

Ozone is one of the most important constituents in the atmosphere and in spite of its low concentration, a few ppmv, 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[1]. The stratosphere itself is dependent on ozone for its existence. The energy absorbed by ozone in the course of creation and destruction of its layer warms the surrounding atmosphere creating temperature inversion. This inverted layer, which is the stratosphere, is very resistant to vertical movements of air and acts as a cap on the turbulent weather processes in the troposphere below. Ozone is also one of the most important constituents in the troposphere and acts as a green house gas trapping the long wave radiation in 9.6 |0,m 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 both incoming solar ultraviolet radiation and outgoing

The reporting of catalytic depletion of ozone by $C10_x$ and NO_x by Johnston[2] (1971) in general and ozone hole over Antarctica in particular by Farman[3] has generated an unprecedented surge of interest in the scientific community in monitoring of ozone. Very low temperature during winter leads to the formation of polar stratospheric clouds (PSCs) [4]. The heterogeneous chemical reactions take place on the surface of polar stratospheric clouds, which is responsible for the ozone hole phenomenon during springtime over Antarctica[4]. After the the discovery of ozone hole and innovative research efforts, it become clear that at low temperature (<-80°C) in the lowest stratosphere, chemical reactions were taking place which needed the presence of liquid or ice particles either as ice or nitric acid trihydrate, or other mixture. They lead to the conversion of chlorine compounds, which normally are present as HC1 and $C10N0_2$ in the stratosphere. Normally these gases do not react with ozone. However, in the presence of ice particles, HC1 and Chlorine Nitrate are converted into Cl_2 and $HN0_3$, and if UV-Solar radiation is available then $C1_2$ is converted into CI atoms, which then react with ozone to form CIO. Thereafter, a new chemical scheme, involving $C1_20_2$ as intermediate, comes into action, which destroys ozone very efficiently.[5"9] However, planetary waves work against CFC-induced ozone destruction. These vast pressure waves influence ozone destruction in several ways and can have relevant impact on the size and stability of the massive jet stream encircling Antarctica called the "Antarctic vortex"[10-11]. Ozone has been found to be strongly affected by the dynamical behavior of the polar vortex[12]. When the strength of planetary waves picks up, they exert a force on the vortex, which blow it apart. As the vortex breaks down, the surrounding warm, ozone-rich air mixes with the cold air over Antarctica, raising ozone concentration observed in Antarctica during ozone hole period[13].

In view of the above a hand held microprocessor based sun photometer, i.e., MICROTOP-II, has been used to measure total ozone, water vapour, optical depth etc. at Maitri, Indian Antarctica research station during the year 2002. 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 *AID* 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[14]. The technical details and theoretical consideration have already been discussed in the DOD technical Report of 16th expedition. In the present communications the results obtained will be discussed in detail.

Results and Discussion

The total column ozone was measured during voyage to Antarctica to study the latitudinal distribution of ozone from 28.65° N to 70.76° S. The variation of total ozone during local noontime with latitude is depicted in the Fig. 1. The gap in the figure is due to non-availability of the data during Airplane voyage from Goa, India to Cape Town, South Africa. The ozone values found to be higher at mid and high latitudes while minimum at tropical latitudes. This is on expected lines and in agreement with other satellite and ground based measurements.

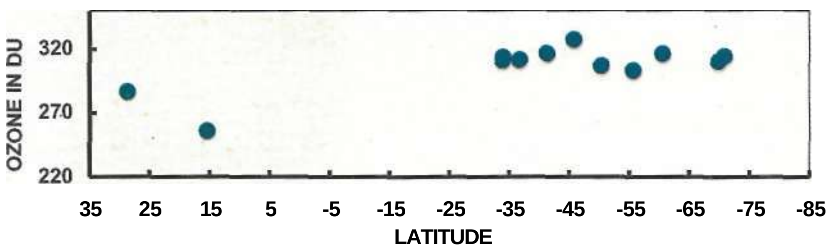

Fig. 1: Latitudinal distribution of total column ozone during Jan.2002

The variation of total column ozone from January 2002 to December 2002 is shown in Fig. 2. The maximum ozone up to 320 DU has been recorded in the months of January and February. The gap in the figure is due to non-availability of data during polar night. The minimum value of total ozone of about 185 DU was observed in the last week of September in the year 2002. The observation shows that the ozone hole in the year 2002 was not as deep as it was recorded in the previous years. The observation also shows the early recovery of ozone hole in the year 2002.

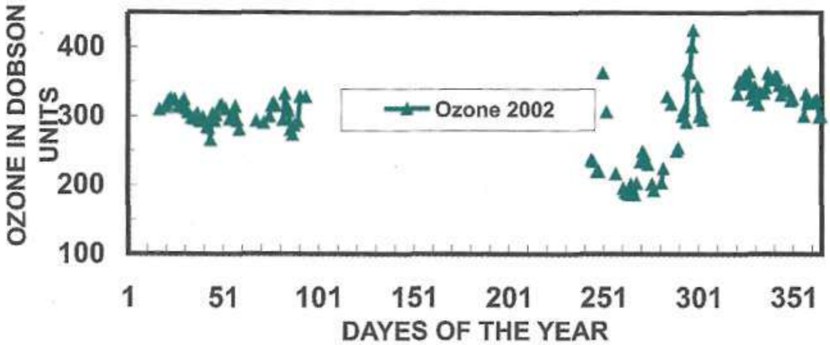

Fig. 2: The variation of Column Ozone during 1997 and 2002 at Maitri, Antarctica

The ozone depletion was started from 1st September onwards. Exceptionally high values up to 361DU of total ozone column were observed during ozone hole period during 7th and 8th September 2002. As shown in Fig. 2 ozone hole started recovering around 23rd September, however, unusual variations were observed during recovery period The variation of total column ozone from TOMS data at different station situated over the fringe region and middle of the Antarctica is shown in Fig. 3. The observation shows that over all the stations exceptional variation of ozone concentration were observed which confirms the unusual behavior and early recovery of the ozone hole observed in the year 2002.

The observation at Maitri showed recovery of ozone hole around 24 - 25 September 2002. The early recovery of ozone hole in last week of the September in 2002 can be explained by Kondratyev and Varotsos[16] finding. Varotsos[17] have performed a Fourier analysis of the 10 hpa height and the temperature time series at the high latitude of the southern hemisphere. He found that extremely large amplitude of planetary waves

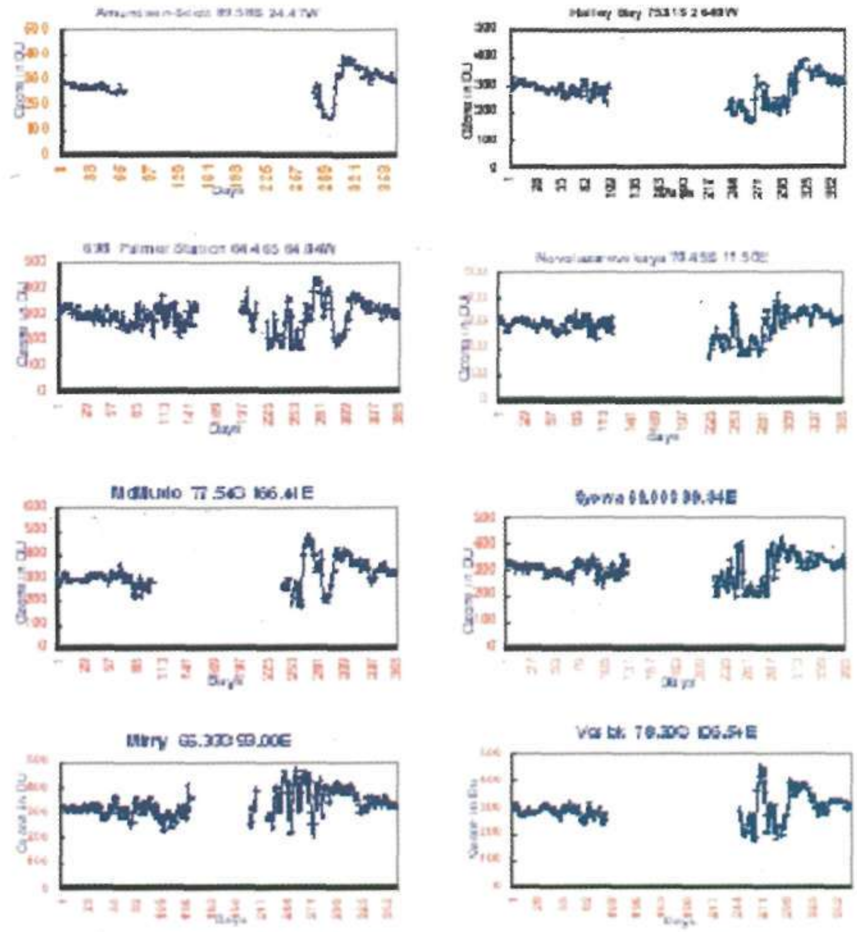

Fig. 3: *TOMS total column ozone data over selected location of Antarctica*

were present which broke up Antarctic ozone hole into two holes[17] on 24-25 September, 2002. After the breakup, the polar vortex reforms and subsequently disappeared very early. NASA press release[18] also represented the prevalence of strong planetary waves in Antarctica as unusual heat flux transfers by planetary waves over 20° to 90° S.

The Maitri Station is situated in the fringe region of the vortex. The observed abrupt high total ozone on 7th, 8th September and also during recovery period from 23rd September onwards as shown in Fig. 2 may be attributed to the planetary wave phenomenon. The planetary wave phenomenon forces the ozone rich air masses from mid latitude to polar latitude region and the rapid displacement of the polar vortex from a roughly symmetric circulation about the pole to a circulation that is offset from the pole, which leads to the stratospheric sudden warming for a short period over the fringe region of the vortex. If the strengths of these waves is high enough then this forces the ozone rich air mass into the polar vortex and sudden increase in the total ozone may takes place[19~21]The observations taken at Maitri were compared with TOMS[15] as well as nearby Russian station (70° 46'S, 11° 50'E) data and found to be in very good agreement as depicted in Fig. 4.

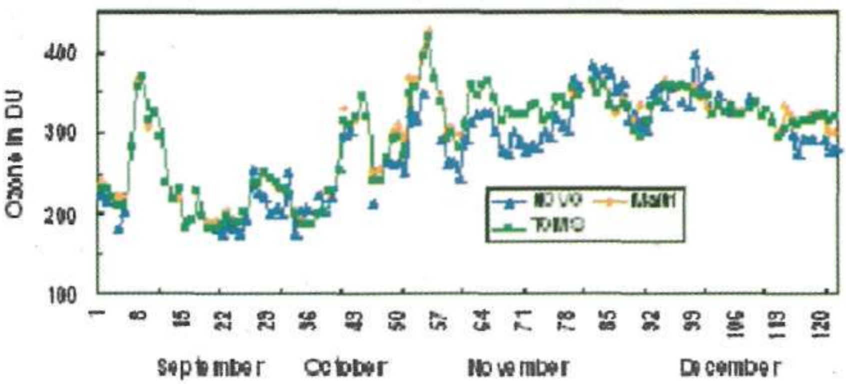

Fig. 4: Comparison of Maitri, Russian and TOMS column ozone over Maitri during ozone hole period

Conclusion

The measurement of total ozone by Microtop Sun photometer at Maitri Station Antarctica during 21^{st} Antarctica Scientific Expedition showed the earlier recovery of ozone hole in the year 2002 which can be attributed to major stratospheric warming due to the prevalence of very strong planetary waves. The agreement between the TOMS data and the sun-photometer data has proved MICROTOP-II sun-photometer to be an important tool to measure total ozone. These measurements indicate that the ozone hole is not worsening, and may soon start to improve. However, this improvement is going to come very slowly.

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