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OZONE HEIGHT PROFILES USING LASER HETERODYNE RADIOMETER

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ABSTRACT

The monitoring of vertical profiles of ozone and related minor constituents in the atmosphere are of great significance to understanding the complex interaction between atmospheric dynamics, chemistry and radiation budget. An ultra high spectral resolution tunable CO_2 laser heterodyne radiometer has been designed, developed and set up at the National Physical Laboratory, New Delhi to obtain vertical profiles of various minor constituents the characteristic absorption lines in 9 to 11 µm spectral range. Due to its high spectral resolution the lines can be resolved completely and data obtained are inverted to get vertical profiles using an inversion technique developed by the author. In the present communication the salient features of laser heterodyne system and the results obtained are discussed in detail.

1. INTRODUCTION

The study of minor constituents in the atmosphere is of vital interest to understand the structure of troposphere and stratosphere. The evidence of catalytic destruction of ozone[1] by NOx and ClOx in the early seventies and the reporting of " ozone hole" [2-3] in the at Antarctic in spring has generated an unprecedented surge of interest in the measurement of various minor constituents in the atmosphere.

A tunable CO_2 laser heterodyne system has been designed, developed and set up at the National Physical Laboratory, New Delhi to monitor various trace species in the troposphere and stratosphere. The system has been used successfully to obtain vertical profiles of ozone.

2. LASER HETERODYNE SET UP

Infrared laser heterodyne spectroscopy provides a powerful tool for identification of trace species. The advantages of the laser heterodyne system over other techniques are its ultra high spectral resolution, high spatial resolution, high quantum detection efficiency and very good signal to noise ratio. The high resolution makes the system very selective as the interference problem due to overlapping lines or bands are minimized.

The block diagram of the system designed, developed and set up at NPL is depicted in Fig.1. The CO_2 laser used as a local oscillator is tuned on a line corresponding to the absorption line of the minor constituent of the interest. The solar tracker (heliostat) follows the sun and brings in the solar radiation. The incoming chopped solar radiation is filtered out and IR radiation (8-12 µm) and CO2 laser beam of moderately low power are combined via a zinc selenide beam splitter. The solar radiation and CO2 laser beam are coaligned and focused on the high speed liquid nitrogen cooled Hg Cd Te detector which acts as a mixer as well as a narrow band filter. The IF signal is amplified and passed through various filter channels (25-1200 MHz). The signal from various channels is square law detected and synchronously detected. The observations taken at different frequency channels in the wings of the absorption line are used to get the vertical profile using inversion technique. The system has been described in detail elsewhere [4-6]. The present system is manually operated butis being automated using 1 GHz acousto- optic spectrometer.

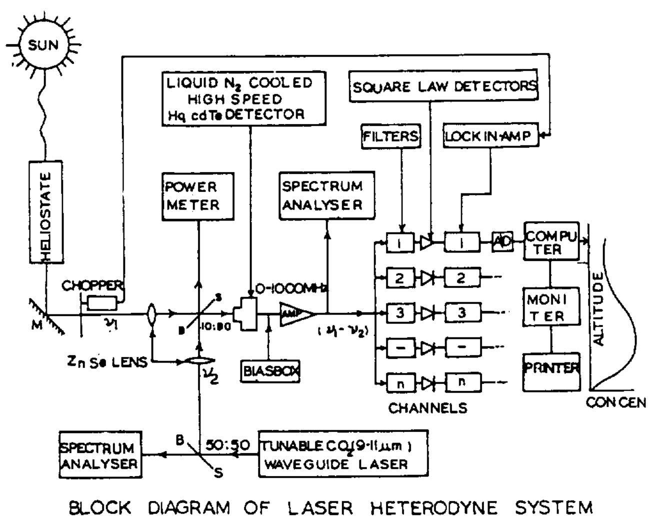

Fig.1 Block diagram of the laser heterodyne system

3. INVERSION TECHNIQUE

The concentration profile or temperature profile can be obtained by analysis of an individual spectral line measured at ultra high resolution through inverse solution of radiative transfer equation [7-10]. A software programme has been developed and tested to obtain the altitude profiles for water vapour, ozone, nitrogen dioxide and ammonia. It is found that the retrieved profiles match well with the model profiles and are independent of the initial guess. Different altitude zones have been considered for Lorentz and Voigt line profiles depending on the constituent of interest. The various line parameters such as line half width, line strength etc were computed in the present work using AFGL HITRAN data base [11] (Nov. 1986). The careful selection of absorption line is made in order to get sharp contribution functions and hence good height resolution. The contribution functions, which depend on absorption coefficient, have a property of reaching a maximum at different altitudes for different frequencies. The computations are made for line center and in the wing of the line. The inversion technique developed for ozone height profile has been discussed in detail by the author [10].

4. RESULTS AND DISCUSSION

The laser heterodyne system is being used to get vertical profiles of ozone. The absorption line selected is 1043.1775 cm^{-1}. A large number of vertical profiles for ozone in the altitude range 15 to 40 km have been retrieved [10]. The Fig.2 shows the range of ozone variation with altitude during 1987-88. The ozone profiles

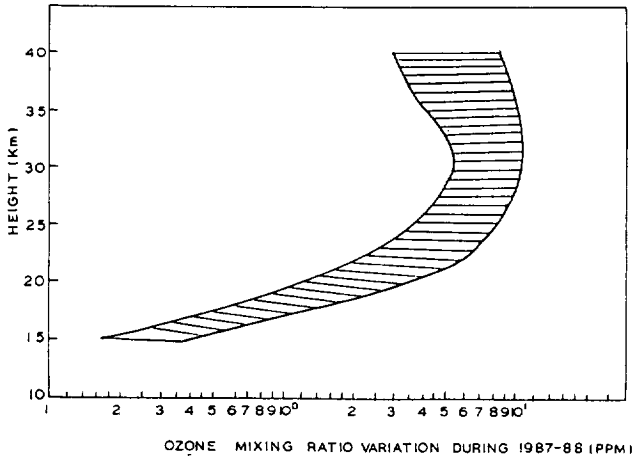

Fig.2 Range of height profile of ozone mixing ratio obtained by laser heterodyne system at NPL, New Delhi during 1987-88.

obtained by the laser heterodyne system at NPL were also compared with those obtained by balloon at Aya Nagar, India Meteorological Department, New Delhi[12], on the days when data were available for both the systems. The two sets of profiles compare well within the experimental error. One typical example for 10-2-1988 is shown in Fig.3. A mean profile from all the data available from the laser heterodyne system has been obtained. This mean profile has also been compared with the mean profiles obtained from balloon ozone sonde data at Aya Nagar, New Delhi and also over Thumba from rocket and balloon ozone sonde (Subaraya[13]) and is shown in Fig.4. The mean profile at New Delhi from the Laser heterodyne system and the balloon ozone sondes compare well but the values of the ozone mixing ratio over Thumba are slightly lower below the peak and greater above the peak. This may be attributed to the latitudinal differences of the two places of measurements.

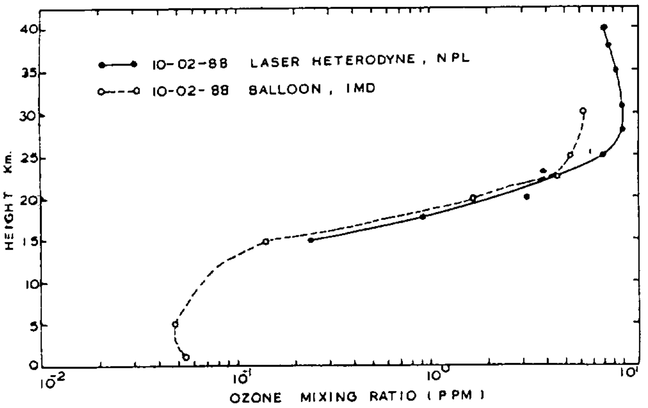

Fig.3 Comparison of ozone mixing ratio profile obtained by laser heterodyne system at NPL, New Delhi and balloon at Aya Nagar IMD, New Delhi on 10.12.1988.

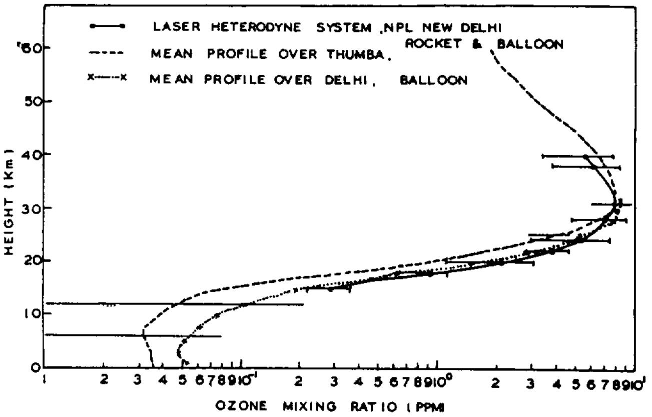

Fig.4 Comparison of mean ozone vertical profiles by, I. laser heterodyne system NPL, New Delhi, II. balloon IMD, at New Delhi, III. rocket and balloon at Thumba.

5. CONCLUSION

The laser heterodyne system set up at the National Physical Laboratory has demonstrated successfully its capability to monitor ozone mixing ratio profiles in the atmosphere. Efforts are continuing to extend the facility to monitor other constituents such as NH_3, SO_2,CFM's etc. The system will be made automatic in due course by using a 1-GHz acousto-optic spectrometer to increase the efficiency of the system to obtain line profiles of various trace species. This type of measurements will go a long way to help understand the complex interaction between atmospheric dynamics, chemistry and radiation budget which in turn requires a large data base on regular basis.

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