N91-71522

DIFFERENTIAL ABSORPTION LIDAR (DIAL) MEASUREMENTS OF STRATOSPHERIC OZONE

Thomas J. McGee
NASA/Goddard Space Flight Center
Laboratory for Atmospheres
Greenbelt, MD 20771

Differential Absorption Lidar (DIAL) measurements of ozone have been made for a number of years, but the recent development of high powered lasers in the ultraviolet now allow for ground based measurements in the 40-45 kilometer regime. Tunable XeCℓ lasers with low divergence and high output powers are now commercially available and are the main laser systems proposed for stratospheric O_3 measurements from the ground or from space.

A DIAL instrument consists of a transmitter, which emits two wavelengths ("on-line" and "off-line") into the atmosphere, and a receiver, comprising a telescope, wavelength separator, and detectors. The scattering medium can be a topographic target or atmospheric scattering (Mie or Rayleigh). If atmospheric scattering is used, range resolution is achieved by time gating the detector electronics relative to the transmitted laser pulse. The attenuation due to ozone (and therefore its number density) can be extracted from a comparison of adjacent range cells.

The lidar equation for the absorption of backscattered radiation can be written:

$$C_{\lambda Z} = I_\lambda \varepsilon_\lambda \frac{A}{4\pi} \int_{Z_1}^{Z_2} N(Z)\ \sigma_{s\lambda} \frac{e^{-\alpha Z}}{Z^2}\, dZ \tag{1}$$

where

$C_{\lambda Z}$ = the number of counts received at wavelength λ from a distance Z.

I_0 = the number of photons emitted at λ.

ε_λ = the total detector efficiency at wavelength λ.

A = the area of the receiver telescope.

N(Z) = the number of scatterers as a function of Z within the range cell.

$\sigma_{s\lambda}$ = the scattering cross section at wavelength λ.

$\alpha = 2[n_{O_3}\sigma_{O_3\lambda} + n_s(Z)\sigma_{s\lambda}]$ where n_{O_3} and n_s are the number densities of ozone and atmospheric scatterers respectively.

Z = the range from the detector.

Ratioing the returns from adjacent range cells for both the on-line and off-line wavelengths and rearranging we can arrive at:

$$\ell n \frac{C_{11}C_{22}}{C_{12}C_{21}} = (\alpha_1 - \alpha_2)\ \Delta Z \qquad (2)$$

where the first subscript refers to the wavelength (1 = on-line, 2 = off-line) and the second subscript refers to the range cell. It is apparent from equation (2) that all the instrumental parameters have dropped out of the expression.

Measurements of stratospheric ozone using the DIAL technique have been performed by a number of different groups. Heaps, et al.[1] measure ozone from a balloon-borne package using a frequency doubled dye laser tuned to an OH absorption line. The purpose of these measurements is to provide a correction to the atmospheric transmission at the OH absorption frequency.

Uchino, et al.,[2] Pelon and Megie,[3] and Werner, et al.[4] have all made measurements of stratospheric ozone from the ground using XeCℓ based lidar systems. The French group have also made O_3 measurements with a dye laser lidar.

Werner, et al. have made measurements up to 50 km in and claim that the statistical error in their measurements is less than 1%. All night integration is required to achieve this accuracy above 40 km. The reference wavelength at 338 nm, was generated by Stimulated Raman Scattering in methane. The instrument was situated at the summit of the Zugspitze.

Pelon and Megie have reported measurements from the Observatoire de Haute-Provence also using XeCℓ for the on-line frequency. This group used a tripled Nd-YAG (355 nm) for the reference wavelength. Ozone was measured between 25 and 50 km. Error bars above 40 km were greater than 15-20% and increased rapidly with altitude.

Uchino, et al. have also published results based on a low energy, low rep-rate XeCℓ laser up to an altitude of 30 km with error bars of approximately 50%. They indicated that later measurements would be made using a more powerful laser system.

In addition to these groups there are two others, one at JPL and one at GSFC, which are preparing to make measurements of stratospheric ozone from the ground with XeCℓ lidars.

Beyond the ground based systems a XeCℓ lidar system has been discussed for the EOS platform. This system would be capable of measuring ozone profiles down to the ground.

References

1. W. S. Heaps, T. J. McGee, R. D. Hudson, and L. O. Caudill, Appl. Opt., 21, 2265, 1982.
2. O. Uchino, M. Maeda, T. Shibata, M. Hirons, and M. Fugiwara, Appl. Opt., 19, 4175 (1980).
3. J. Pelon and G. Megie, 12th International Laser Radar Conference, Aix-en-Provence, France, pg. 247, August 13-17, 1984.
4. J. Werner, K. W. Rothe, and H. Walther, 12th International Laser Radar Conference, Aix-en-Provence, France, pg. 225, August 13-17, 1984.