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Data set Description:
PI: G. Ancellet
Instrument: UV DIAL lidar
Site: Observatoire de Haute Provence
Measurement Quantities: Tropospheric Ozone

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References Articles:
G. Ancellet, A. Papayannis, J. Pelon, and G. Mégie, 1989: DIAL Tropospheric Ozone Measurement Using a Nd:YAG Laser and the Raman Shifting Technique. J. Atmos. Oceanic Technol., 6, 832¿839, https://doi.org/10.1175/1520-0426(1989)006<0832:DTOMUA>2.0.CO;2

G.Ancellet and M.Beekmann. Evidence for changes in the ozone concentration in the free troposphere over Southern Europe from 1976--1995. Atmos. Environ., 31(17):2835--2851, 1997.

M.Beekmann, G.Ancellet, D.Martin, C.Abonnel, G.Duverneuil, F.Eideliman, P.Bessemoulin, N.Fritz, and E.Gizard. Intercomparison of tropospheric ozone profiles obtained by electrochemical sondes, a ground-based lidar and an airborne UV-photometer. Atmos. Environ., 29(9):1027--1042, 1995.

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A. Gaudel, G. Ancellet, S. Godin-Beekmann, Analysis of 20 years of tropospheric ozone vertical profiles by lidar and ECC at Observatoire de Haute Provence (OHP) at 44°N, 6.7°E, Atmospheric Environment, Volume 113, 2015, Pages 78-89, https://doi.org/10.1016/j.atmosenv.2015.04.028.

Instrument Description:
A Nd-YAG laser is used in combination with a Raman cell filled up with Deuterium or Hydrogen to generate two wavelengths simultaneously transmitted to the atmosphere: 289 and 299 nm (before March 1993) and 289-316 nm (since March 1993). A 80-cm telescope is used to collect the backscattered light and is coupled to a grating spectrometer for wavelength separation and background sky light filtering. The full geometrical overlap between the telscope field of view (1.0 mrd) and the laser beam is obtained at ranges above 3.5 km.

Output of 2 PhotoMultiplier Tubes (PMTs) are recorded by photocounting and analog detection. The combination of two different detection methods provides a dynamical range larger than 10 km for the lidar measurement in the free troposphere.

From 1990 to 2011, the data acquisition system was designed at CNRS (12-bits, 10-MHz Analog Device ADC and 300 MHz counters operated with 250 ns time gates). Since 2012 the data acquisition system is a LICEL system with two TR-2080 transient recorder.

Although daytime measurements are possible, the lidar is usually operated at sunset to reduce the background noise. Lidar signal are usually averaged during 100 s (2000 laser shots).

Data processing

The 100 s averages are further added to improve the signal to noise ratio. In practise, the averaging time varies between 30 and 60 min. Range averaging of the range corrected signal is performed with a numerical low pass filter which corresponds to a 2nd order polynomial fit over a numberof points increasing with range. The number of bins is calculated to obtain a range resolution of 100 m at 1.5 km and 1000 m at 10 km. The geometrical compression is corrected using a model of the overlap function to retrieve ozone data down to a 1.8-km range (2.5 km ASL altitude). The divergence of the transmitted beams were determined experimentally for each wavelength and the misalignment between the laser beams and the telescope is assumed to be wavelength independent since the two beams are transmitted coaxially.

This misaligment angle to select the appropriate overlap functions is determined by fitting the 316-nm signal derivative to the molecular attenuation in the 3-5 km range. The background noise correction of the analog signal is optimized to fit the analog signal log derivative with the counting signal log derivative. The background noise correction of the photocounting signal is optimized by fitting the lidar signal with a decreasing function to account for detector overload at short ranges.

The ozone absorption cross sections used for the ozone calculation are taken after the work of Bass and Paur but using the Molina and Molina (1986) cross section temperature dependency. Correction of the molecular extinction (Rayleigh extinction) is based on an atmospheric density model which depends on the season and the latitude band (Chedin et al., 1985).

Chedin, A., N.A. Scott, C. Wahiche and P. Moulinier (1985), The Improved Initialization Inversion Method: a high resolution physical method for temperature retrievals from satellites of the TIROS-N serie, J. of Climat. and Appl. Meteor. 24, 2.

Molina L. and M..Molina (1986) Absolute absorption cross sections of ozone in the 185 to 350 nm wavelength range, J.Geophys.Res., 91, D13, 14501-14508.

Error analysis

When no significant aerosol layers are present, the DIAL measurements are limited first by statistical errors related to the decreasing signal-to-noise ratio at far ranges and second by systematic errors arising from instrumental limitations, namely the geometrical error at near range and electronic noise in the analog signal. Only the statistical error is reported in the NDACC data files.

At near range below 4 km, the DIAL measurement remain subject to a bias related to differences between the geometrical telescope overlap function of each emitted laser beam and the telescope field of view. The shortest distance where measurement is possible is 1800 m since ozone error are larger than 15 ppb at shorter ranges. Residual noise at frequencies less than 50 kHz are frequently apparent in the analog signals and are not always suppressed by averaging.

The aerosol backscatter coefficient is calculated at 316 nm where ozone absorption is negligible, using a backward integration scheme described by (Browell et al., 1985). A 316-nm extinction to backscatter ratio of 33 is generally chosen corresponding to continental aerosol in the work of Browell (1985). This information is used to verify whether significant aerosol layers are present in the measurement area, but aerosol is usually not performed. Cloud layers are always identified and ozone data are removed from these area because no valuable corrections can be made in such conditions.

Browell, E., S.Ismail, and S.Shipley (1985) Ultraviolet DIAL measurements of ozone profiles in regions of spatially inhomogeneous aerosols, Appl.Opt., 24, 2827-2836.

Instrument history

Beginning of the first routine measurements in 1990 at OHP

1) two Raman cells were used to generate the wavelengths 289, 299 nm
2) the two-cell system was sensitive to the alignment below 5 km
3) Old laser with unstable 4th harmonic generator

02/1993 Change of the laser (Continuum Surelite) and move to a single cell system as described above

01/1996 Change of the processing software (Fortran code --> Matlab code)
The main change in the processing is to combine the counting and analog slopes before the ozone calculation while before two ozone profiles were calculated for the analog and counting signals. This allows a better overlap of the two recording modes

11/1998 to 03/1999 Breakdown of the data acquisition system. Installation of a new waveform recorders.

05/2001 to 07/2002: Maintenance of laser and data acquisition system

08/2004 to 02/2005: Laser failure. Installation of a new SURELITE laser.

10/2011 to 03/2012: New lidar installation (shorter distance between laser optical table and telescope, optical alignment is more stable) Installation of the LICEL data acquisition system instead of the LATMOS home made system

03/2013 to 12/2013: Several laser failure (4th harmonic generator). Installation of a Pellin Broca prism to improve the 4th harmonic generator lifetime