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Data Set Description:

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Instrument: DIAL Stratospheric Ozone lidar
Site(s): Observatoire de Haute Provence (OHP, 43.9°N, 5.7°E,)
Dumont d'Urville (DDU, 66.4°S, 140°E)
Measurement Quantities: Ozone (15-50 km)

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Reference Articles:

- Pelon, J., S. Godin, G. Mégie, Upper Stratospheric (30-50 km) Lidar Observations of the Ozone Vertical Distribution, *J. of Geophys. Res.*, 91, D8, 8666-8671, 1986
- Godin S., G. Mégie, J. Pelon : Systematic Lidar Measurements of the Stratospheric Ozone vertical Distribution, *Geophys. Res. Letters*, Vol 16 No 16, 547-550, 1989
- Lacoste A.M., S. Godin, G. Mégie : Lidar measurements and Umkehr observations of the ozone vertical distribution at the Observatoire de Haute Provence, *J. Atm. Terr. Phys.*, Vol 54, 5, 571-582, 1992
- Stefanutti L., F. Castagnolli, M. Del Guasta, M. Morandi, V.M. Sacco, L. Zuccagnolli, S. Godin, G. Megie, J. Porteneuve : The Antarctic Ozone Lidar System, *Appl. Phys. B* 55, 3-12, 1992
- Godin S., C. David M. Guirlet, Evolution of the Mt. Pinatubo Volcanic Cloud and Analysis of its Effect on the Ozone Amount as Observed from Ground-Based Measurements Performed in Northern and Southern Latitudes, NATO ASI series, Subseries I "Global Environment change", Vol 42, ed. by G. Fiocco et al., 1996
- Gibson-Wilde D.E, R.A. Vincent, C. Souprayen, S. Godin, A. Herzog, S.D. Eckermann, Dual lidar observation of mesoscale fluctuations of ozone and horizontal winds, *Geophys. Res. Lett.*, 24, 13, 1627-1630, July, 1, 1997
- Godin S., A. Carswell, D. Donovan, H. Claude, W. Steinbrecht, S. Mcdermid, T. Mcgee, M.R. Gross, H. Nakane, D.P.J. Swart, J.B. Bergwerff, O. Uchino, P. Von Der Gathen, R. Neuber, Ozone Differential Absorption Lidar Algorithm Intercomparison, *Appl. Opt.*, Vol 38, 30, 6225-6236, 1999.
- Guirlet, M., Keckhut, P., Godin, S. and Mégie, G., Description of the long-term ozone data series obtained from different instrumental techniques at a single location: The Observatoire de Haute-Provence (43.9 °N, 5.7°E), *Ann. Geophys.*, 18, 1325-1339, 2000.

Godin S., V. Bergeret, S. Bekki, C. David, G. Mégie, Study of the interannual ozone loss and the permeability of the Antarctic Polar Vortex from long-term aerosol and ozone lidar measurements in Dumont d'Urville (66.4°, 140°S), J. Geophys. Res., 106, 1311-1330, 2001.

Instrument Description:

1. OHP

Ozone measurements are performed using the DIAL (Differential Absorption Lidar) technique which requires the simultaneous emission of two laser beams characterised by a different ozone absorption cross-section. At OHP, the absorbed laser radiation is emitted by a Lambda Physics EMG 150 XeCl excimer laser at 308 nm and the reference line is provided by the third harmonic of a Continuum Nd:Yag laser at 355 nm. Both lasers operate at 50 HZ and the output energies are 200 mJ at 308 nm and 40 mJ at 355 nm. Beam expanders are used to reduce the divergence of the excimer laser to 0.2 mrad and of the Nd:Yag laser to 0.1 mrad. The optical receiving system consists of four similar F/3 mirrors of 53 cm diameter, which correspond to an equivalent receiving surface of 1.06 meter diameter. Both laser beams are emitted in the center of the collecting area so that each mirror acts as the receiver of an elementary lidar but the whole system is quasi-coaxial. The light is collected by four optical fibers of 1 mm diameter mounted in the focal plane of each mirror. The fiber mounts can be moved manually in the vertical direction for focalization adjustment. They are motorized in the X-Y directions to position the fibers exactly on the image of the scattered light. After detection, the optical fibers transmit the backscattered light to the optical analyzing device which includes imaging optics, a mechanical chopper and a multichannel monochromator designed for the wavelength separation. The chopper consists of a 40 Watts cooled motor which drives a blade of 140 mm diameter and 20 mm width, rotating at 24000 rpm in primary vacuum. The 1 mm fibers are assembled together on a line in a specially designed mount which enables a sharp desobturation of the laser signal in 5.7 μ s. The monochromator uses a 3600 grooves/mm holographic grating characterized by a dispersion of 0.3 nm/mm and a bandwidth of 1.5 nm. The global transmission for each wavelength is about 0.45. The detected wavelengths are 308 nm, 355 nm and the corresponding 1st Stokes wavelengths in the Nitrogen vibrational Raman spectrum (332nm and 387 nm). The backscattered signals related to these wavelengths are used to reduce the volcanic aerosol inference on the measured ozone number density. At the output of the monochromator, the elastically backscattered signal at 308 nm and 355 nm are separated into a low and a high altitude channel in order to account for the dynamic of the lidar signals in the measurement altitude range, so that in total the lidar set up includes 6 optical channels.

Optical signal detection is made by Hamamatsu photomultiplier tubes running on a counting mode. Counting gating is 1 microsecond providing a 150 meter vertical resolution. The signals are recorded on a 1024 microsecond time range which corresponds to roughly 150 km. In addition to the use of mechanical chopper, electronic gating is used on the high energy Rayleigh channels, in order to suppress signal induced noise resulting from the initial burst of light at lower altitudes. The whole experiment is run by a PC. Lidar signals are stored in 10000 shots files providing a temporal resolution of 200 seconds. For each file, the raw signals are displayed during the experiment and a signal pre-processing is made every 30000 shots in order to display the slopes of the signals and the corresponding ozone profile.

2. Dumont d'Urville

At Dumont d'Urville, the DIAL system is part of a multispectral lidar system intended to measure Polar Stratospheric Clouds and the ozone vertical distribution. A detailed description of the whole lidar system can be found in Stefanutti et al., 1992. The transmitter consists of two lasers, a Nd:Yag laser (Quanta System) and a XeCl excimer laser (Lambda Physik EMG 150) working at 10 Hz and 80 Hz respectively. In the DIAL mode, the third harmonic of the Nd:Yag radiation at 355 nm is used. Output energies are 150 mJ at 308 nm and 40 mJ at 355 nm. The receiver is an 0.8 m F/9 aluminium Cassegrain telescope. The beam is collimated and by means of a dichroic beamsplitter, the UV radiation is separated from the visible radiation and sent to a multichannel monochromator which uses a holographic grating with 3600 grooves/mm for the wavelength separation. Only the elastically backscatter (at 308 nm and 355 nm) are used for ozone retrieval although the spectrometer design permits the detection of the 1st Stokes Nitrogen vibrational Raman wavelengths. The signal at these wavelengths was found to be too low in the present system configuration for correct ozone retrieval. As at OHP, the elastically backscattered signal at 308 nm and 355 nm are separated into a low and a high altitude channel in order to account for the dynamic of the lidar signals in the whole stratosphere so that in total 4 channels are used for ozone retrieval. At each channel, the signal is detected by a Hamamatsu photomultiplier. No mechanical chopper was implemented on the system to prevent for signal induced noise in the photomultipliers so electronic gating only is used to attenuate this effect.

For electronic detection, both A/D conversion and photon counting have been adopted for the whole lidar system. In the DIAL mode, only photon counting is used. The 4 photon counting channels work simultaneously. Each one is based on LeCroy units comprising a multichannel scaler of 1 microsecond dwell time. A LeCroy MAGIC controller model 6010 is used for the interface of the LeCroy CAMAC bus to the GPIB port of the PC that runs the whole experiment.

Algorithm Description:

The same algorithm is used for processing the OHP and DDU data. The main difference is the lack of Raman signals in the case of DDU so the ozone vertical distribution is retrieved from the Rayleigh signals only.

In the routine mode, the lidar signals are time averaged over the whole measurement period (3 to 4 hours in general) in order to increase the signal-to-noise ratio. Each averaged signal is then corrected from the background light which is estimated using a linear regression in the altitude range where the lidar signal is negligible (80 - 150 km). In the DDU case the signal induced noise affecting the high energy Rayleigh channels is more important due to the lack of mechanical chopper. Therefore a more complex function is often required to fit the background signal in the upper range part. In our case, a parabolic fit of the logarithm of the signal was found to provide the best results. Another correction is applied on the lidar signals in order to account for the dead time effect in the photon counters mode. This correction is detailed below.

The ozone number density is retrieved from the derivation of the logarithm of the corrected lidar signals. It is also necessary in the DIAL technique to use a low-pass filter in order to account for the rapid decrease of the signal-to-noise ratio in the high altitude range. In our case, the logarithm of each signal is fitted to a 2nd order polynomial and the ozone number density is computed from the difference of the derivative of the fitted polynomial. The smoothing is achieved by varying the number of points on

which the signals are fitted. The ozone number density is derived from the three lidar signal pairs detected by the experimental system: Rayleigh high energy, Rayleigh low energy and Raman, which optimize the precision of the retrieved ozone profile in the high stratosphere, the middle-low stratosphere and the lower stratosphere respectively. The Raman wavelengths provide an ozone profile much less perturbed by the presence of volcanic aerosols than the Rayleigh ones but due to the smaller Raman scattering efficiency, the Raman signals are less energetic and the vertical resolution of the Raman ozone profile has to be reduced as compared to the Rayleigh one. In condition of low stratospheric background aerosol, it is thus preferable to use the low energy Rayleigh signals. In order to check the linearity of these signals in the lower stratosphere and correct the photon counting dead time effect, the following procedure is applied: the Raman signals and the corresponding Raman ozone profile are used to compute a « reference Rayleigh » slope at each wavelength. The parameter used for the dead time correction of the Rayleigh signals is then adjusted to obtain the best fit with the « reference Rayleigh » slope. The same procedure is applied to check the linearity of the high energy Rayleigh channels but this time against the low energy Rayleigh slopes. The dead time correction is adjusted in order to obtain the best agreement between the low energy and the high energy Rayleigh slopes. The ozone profile is retrieved first by combining for each wavelength the slopes of the low energy and high energy Rayleigh signals and then by combining the Raman and the composite Rayleigh ozone profiles. The altitude range where the Raman and the Rayleigh profiles are combined depends on the aerosol content in the low stratosphere. In the DDU case, the linearity of the low energy 355 nm channel can be checked only against a model slope calculated using PTU radiosonde data that are provided at the station once a day by the French Met. Office. But the same procedure is applied for the high energy Rayleigh channels.

Finally, the ozone number density is corrected from the Rayleigh extinction using composite pressure-temperature profiles computed from nearby radiosoundings performed in Nîmes in the case of OHP or at the station itself in the case of DDU, and the CIRA model. Part of the present ozone algorithm can be found in Godin et al., 1999.

Expected Precision/Accuracy of Instrument:

The accuracy of the ozone lidar measurement depends on the correction of the differential molecular and aerosol scattering, the differential absorption by other constituents and on the temperature dependence of the ozone absorption cross-sections (Godin et al., 1989). The maximum residual random error after correction is estimated to 3 % in the case of background aerosols. The precision of the measurement corresponds to the statistical error of the signal due to the random character of the detection process which follows basically the Poisson statistics. Among other parameters such as the power of the lasers and the telescope detection area, it depends on the duration of the measurements and the vertical resolution chosen to process the data. At OHP, the total accuracy varies from about 3 % to 20 % in the 15-50 km altitude range, for a corresponding vertical resolution ranging from 0.4 to 6 km and a typical temporal resolution of 4 hours.

At DDU, a typical experiment lasts 3 - 4 hours and ozone vertical distribution is retrieved from 12 to 35 - 40 km. The vertical resolution ranges from 0.5 km at 12 km to 4 km at 35 km, with a corresponding total uncertainty varying from 3 to 15 % in the same altitude range and in the absence of PSC. Indeed, a

correct retrieval of the ozone number density is impossible in the presence of PSC or volcanic aerosol at the altitude of the cloud. In this case, ozone profiles are provided above the altitude of the cloud.

Instrument History:

At OHP, systematic stratospheric DIAL ozone measurements began in 1986. The main features of the lidar set-up were 2 laser sources (a XeCl excimer laser and a Nd:Yag laser) providing the absorbed (308 nm) and the reference (355 nm) wavelengths respectively, a 80 cm diameter cassegrain telescope, detecting optics including photomultiplier tubes to record the laser light and 2 counting channels linked to a PC microcomputer for the acquisition (Godin et al., 1989). At the output of the telescope, a 308 nm Rmax mirror was used to separate the laser radiations which were further selected by interferential filters. Due to the large dynamic of the lidar signals, 2 measurements had to be made sequentially in order to cover the 18-45 km altitude range. A first measurement with the full laser energy and the second one using a glass window at the output of the telescope in order to attenuate the lidar signal at both wavelengths. The change of the lidar experimental system to the present configuration was made in December 1993.

A first intercomparison with the GSFC mobile lidar was made in July 1992, one year after the eruption of Mount Pinatubo. At that time the OHP lidar did not detect the Raman wavelength so the ozone profile were obtained from 25 km only. A second intercomparison campaign was organized in 1997. Results show in general a very good agreement between the OHP and GSFC lidars except for a small positive bias of 3 - 5 % around the altitude of the ozone maximum, of the OHP lidar as compared to the GSFC one.

At DDU, the whole lidar system was implemented in 1991. In 1996, 2 additional photon counting Lecroy units were added to the acquisition system in order to detect the 4 Rayleigh channels simultaneously. Sequential measurements of the low and the middle stratosphere had been made previously.

Our team participated also to the comparison of the derivating-smoothing algorithms used to retrieved ozone from the lidar signals (Godin et al., 1999).