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Data Set Description:

PI: Thierry Portafaix & Sophie Godin Beekman
Instrument: Stratospheric ozone DIAL
Site(s): Reunion island (21.1S, 55.4E)
Measurement Quantities: ozone profiles (12-45 km)

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Reference Articles:

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Baray J-L., et al., : Ma•do observatory: a new high-altitude station facility at Reunion Island (21¡ S, 55¡ E) for long-term atmospheric remote sensing and in situ measurements, Atmos. Meas. Tech., 6, 2865Ð2877, https://doi.org/10.5194/amt-6-2865-2013, 2013

Instrument Description:

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. The absorbed laser radiation is emitted by a XeCl excimer laser (Lumonics PM 844) at 308 nm and the reference line is provided by the third harmonic of a Nd:Yag laser (Spectra-Physics Lab 150) at 355 nm. The excimer laser (308 nm) operates at 40 HZ with an output energies 230 mJ. The Nd:Yag laser (355 nm) operates at 30 HZ with an output energies 150 mJ. An afocal optical system (magnification of the beam expander: x3) is used to reduce the divergence of the beam to 0.5 mrad. The optical receiving system consists of four parabolic mirrors of 50 cm diameter, which correspond to an equivalent receiving surface of 0.78 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. 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 monochromator uses a 3600 grooves/mm holographic grating characterized by a resolution of 3 A/mm and a global transmission for each wavelength 0.40. 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. The current configuration allows the simultaneous acquisition of 6 channels: 2 channels at 355 nm corresponding to the lower and upper parts of the profile, 2 channels at 308 nm (lower and upper parts) and 2 Raman channels at 332 and 387 nm.

Optical signal detection is made by Hamamatsu photomultiplier tubes running on a counting mode. Counting gating is 0.2 microsecond providing a 30 meter vertical resolution. The signals are recorded on a 4096 bins range which corresponds to roughly 120 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 5400 (40 Hz) and 7200 (30 Hz) shots files providing a temporal resolution of 3 minutes. For each file, the raw signals are displayed during the experiment.

Algorithm Description:

The algorithm has been developed in matlab language by Sophie Godin and Andrea Pazmino, and adapted for the Reunion LIDAR by Thierry Portafaix and Guillaume Payen. Recently, a homogenization work has been done between OHP and La Reunion stations (Guillaume Payen and Maud Pastel). The algorithm and software used today for processing the Reunion data (DIAL V5) is the same than this used for processing the OHP data.

In the routine mode, the lidar signals are time averaged over the whole measurement period (2 to 3 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 or a meanin the altitude range where the lidar signal is negligible (80 - 130 km). 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 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.
Finally, the ozone number density is corrected from the Rayleigh extinction using composite pressure-temperature profiles computed from daily radiosoundings performed at Gillot Airport and the Arletty model (above Gillot profile). Only the Arletty model is used before 2006. Part of the present ozone algorithm can be found in Godin et al., 1999 and in Portafaix, 2001.

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 5-8 %. 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 thevertical resolution chosen to process the data. The total accuracy varies from about 5 % to 20 % in the 18-45 km altitude range, for a corresponding vertical resolution ranging from 0.4 to 6 km and a typical temporal resolution of 4 hours.

Instrument History:
The stratospheric ozone DIAL system has been installed at La Reunion in early 2000.
It has been operated from June 2000 until the end of 2006 on the St Denis's Site. It was recently move to the site of "Piton Maido" at 2138 m asl.

The development of this system is issued from a collaboration between the Service d'Aeronomie of University Paris VI (S. Godin, J. Porteneuve), the Laboratoire de Physique de l'Atmosphere, of University of La Reunion (J.L. Baray, T. Portafaix, J.M. Metzger) and the university of Geneva (C. Hirt, C. Flesia).

One significant change in this instrument is the installation of the electronic obturation system in September 2002.

The other significant change is the choice of the disk-chopper.

May 2000 to May 2002, use of a disk chopper with 2 little windows: the signal is obtured at 85 km and it makes the sky noise correction difficult on some profiles.

September 2002: use of a disk chopper with 2 enlarged windows: No problem for the sky noise correction, but this new disk was not stable and destroy the motor of the chopper after 2 nights on 14 September 2002.

Chopper problems was fixed in the end of 2002.

Installation of the two Raman Channels in 2003.

Operations was suspended in 2006 due to different problems with the lasers and the electronic chain.

The Measurements have resumed in february 2013 on the new facility (Maido 2138 m asl) after the change of the electronic chain (LICEL chain) and of the eximer laser.

In addition, ozone measurements are weekly performed by radiosondes at Reunion island since 1992.

Other lidar instrumentations are also operational on the same site: Rayleigh Temperature and aerosols since 1994, tropospheric ozone since 1998, Raman Temperature since 1999, tropospheric water vapor since 2012.