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Data Set Description

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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

Godin S., G. Mégie, and J. Pelon, Systematic Lidar Measurements of the Stratospheric Ozone vertical Distribution, *Geophys. Res. Letters*, Vol 16 No 16, 547-550, 1989.

Bencherif, H., J. Leveau, J. Porteneuve, P. Keckhut, A. Hauchecorne, G. Mégie, and M. Bessafi, Lidar developments and observations over Réunion Island (20.8° S, 55.5° E). In: Ansmann, A., Neuber, R., Rairoux, P., Wandinger, U. (eds) *Advances in Atmospheric Remote Sensing with Lidar*. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-60612-0_134, 1996.

Jean-Luc Baray, Jean Leveau, Jacques Porteneuve, Gérard Ancellet, Philippe Keckhut, Françoise Posny, and Serge Baldy, Description and evaluation of a tropospheric ozone lidar implemented on an existing lidar in the southern subtropics, *Appl. Opt.* 38, 6808-6817, 1999.

Godin S, Carswell AI, Donovan DP, Claude H, Steinbrecht W, McDermid IS, McGee TJ, Gross MR, Nakane H, Swart DP, Bergwerff HB, Uchino O, von der Gathen P, Neuber R., Ozone Differential Absorption Lidar Algorithm Intercomparison, *Appl. Opt.*, Vol 38, 30, 6225-6236, 1999.

Portafaix T., ozone stratosphérique en zone tropicale sud : transport méridien et effets de barrière dynamique, PhD Thesis of the university Paris VI, June 2001.

Portafaix T., B. Morel, H. Bencherif, S. Godin-Beekmann, S. Baldy, A. Hauchecorne., Fine scale study of a thick stratospheric ozone lamina at the edge of the southern subtropical barrier, *J. Geophys. Res.* 108, D6, 4196, doi: 10.1029/2002JD002741, 2003.

Baray, J.-L., Courcoux, Y., Keckhut, P., Portafaix, T., Tulet, P., Cammas, J.-P., Hauchecorne, A., Godin Beekmann, S., De Mazière, M., Hermans, C., Desmet, F., Sellegri, K., Colomb, A., Ramonet, M., Sciare, J., Vuillemin, C., Hoareau, C., Dionisi, D., Duflot, V., Vérémes, H., Porteneuve, J., Gabarrot, F., Gaudo, T., Metzger, J.-M., Payen, G., Leclair de Bellevue, J., Barthe, C., Posny, F., Ricaud, P., Abchiche, A., and Delmas, R., Maïdo 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, 2865–2877, <https://doi.org/10.5194/amt-6-2865-2013>, 2013

van Gijssel, J. A. E., Swart, D. P. J., Baray, J.-L., Bencherif, H., Claude, H., Fehr, T., Godin-Beekmann, S., Hansen, G. H., Keckhut, P., Leblanc, T., McDermid, I. S., Meijer, Y. J., Nakane, H., Quel, E. J., Stebel, K., Steinbrecht, W., Strawbridge, K. B., Tatarov, B. I., and Wolfram, E. A.: GOMOS ozone profile validation using ground-based and balloon sonde measurements, *Atmos. Chem. Phys.*, 10, 10473–10488, <https://doi.org/10.5194/acp-10-10473-2010>, 2010

Thierry Portafaix, Sophie Godin-Beekmann, Guillaume Payen, Martine de Mazière, Bavo Langerock, Susana Fernandez, Françoise Posny, Jean-Pierre Cammas, Jean-Marc Metzger, Hassan Bencherif, Corinne Vigouroux, Nicolas Marquestaut . Ozone profiles obtained by DIAL technique at Maïdo Observatory in La Reunion Island: comparisons with ECC ozone-sondes, ground-based FTIR spectrometer and microwave radiometer measurements. *ILRC 27 Proceedings*, Jul 2015, New-York, United States

Tohir, A. M., Portafaix, T., Sivakumar, V., Bencherif, H., Pazmiño, A., and Bègue, N.: Variability and trend in ozone over the southern tropics and subtropics, *Ann. Geophys.*, 36, 381-404, <https://doi.org/10.5194/angeo-36-381-2018>, 2018

Gantois, D., Payen, G., Sicard, M., Duflot, V., Bègue, N., Marquestaut, N., Portafaix, T., Godin-Beekmann, S., Hernandez, P., and Golubic, E.: Multiwavelength aerosol lidars at the Maïdo supersite, Réunion Island, France: instrument description, data processing chain, and quality assessment, *Earth Syst. Sci. Data*, 16, 4137–4159, <https://doi.org/10.5194/essd-16-4137-2024>, 2024

Millet, T., Bencherif, H., Portafaix, T., Bègue, N., Baron, A., Duflot, V., Clerbaux, C., Coheur, P.-F., Pazmino, A., Sicard, M., Metzger, J.-M., Payen, G., Marquestaut, N., and Godin-Beekmann, S.: Evidence of an Ozone Mini-Hole Structure in the Early Hunga Plume Above the Indian Ocean, *EGUsphere* [preprint], <https://doi.org/10.5194/egusphere-2024-2350>, 2024

Instrument Description

Ozone measurements are performed using the DIAL (Differential Absorption Lidar) technique which requires the simultaneous emission of two laser beams characterized 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 energy of 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 backscattered signal 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 Å/mm and a global transmission for each wavelength 0.40. At the output of the monochromator, the elastically backscattered signals at 308 nm and 355 nm are separated into low- and high-altitude channels 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, 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, then 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 as the one 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 mean in the altitude range where the atmospheric backscattered signal is weak (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.

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 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 must 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 radio-soundings performed at the Roland Garros International Airport and the Arletty model (above Airport 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 PhD thesis (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's statistic law. Among other parameters such as the power of the lasers and the telescope total detection surface, it depends on the duration of the measurements and on the vertical 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 university campus at St Denis. The system was dismantled and reinstalled at altitude on the Maïdo observatory in 2013 (at 2138 m asl).

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

Some significant changes operated on the system

- implementation of the electronic obturation in September 2002
- use of a disk chopper with 2 enlarged windows
- addition of 2 Raman acquisition channels in 2003
- interruption of LiDAR measurements in 2006 due to major problems with the lasers and the acquisition chain
- In August 2012, the system was reinstalled at the new facility (Maïdo observatory, 2138 m asl) and the electronic chain and the Excimer laser were replaced.
- interruption of LiDAR measurements since December 2021 following the COVID pandemic period, due to gas delivery
- the system was involved in the NDACC LIDAR validation campaign with NASA at the Maïdo Observatory, April 2014

Related measurements on the Reunion site

- Tropospheric and stratospheric ozone profiles performed on a weekly basis by radiosondes (since 1992), in the framework of the SHADOZ program (since 1998)
- Daily total ozone columns are recorded by 2 SAOZ spectrometers on the University Campus and at the Maïdo Observatory
- Other LiDAR systems have been operational on the same site:
 - Rayleigh LiDAR for Temperature and aerosols profiling (since 1994)
 - LiDAR for tropospheric ozone (since 1998),
 - Raman-N₂ LiDAR for Temperature (since 1999),
 - Raman-H₂O LiDAR water vapor profiling in the for tropospheric and lower stratosphere (since 2012)
 - Doppler LiDAR for wind measurement (since ??)
 - UV spectroradiometer BENTHAM DTMc300 (since 2009)