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Data Set Description:
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Instrument: Rayleigh-Mie channel of DIAL Stratospheric Ozone lidar (LiO3S)

Site: Alpine Station, Observatoire de Haute-Provence (43.9°N, 5.7°E)

Measurement Quantities: Stratospheric aerosol backscatter and extinction profiles at 355 nm (tropopause to 32 km)

Data Version description: Aerostrato V1.1: stratospheric aerosol backscatter and extinction profiles at 355 nm retrieved from L1 data (nightly-mean raw lidar return)

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Reference Articles:

Khaykin, S. M., Godin-Beekmann, S., Keckhut, P., Hauchecorne, A., Jumelet, J., Vernier, J.-P., Bourassa, A., Degenstein, D. A., Rieger, L. A., Bingen, C., Vanhellemont, F., Robert, C., DeLand, M., and Bhartia, P. K.: Variability and evolution of the midlatitude stratospheric aerosol budget from 22 years of ground-based lidar and satellite observations, Atmos. Chem. Phys., 17, 1829–1845, https://doi.org/10.5194/acp-17-1829-2017, 2017

Khaykin, S. M., Godin-Beekmann, S., Hauchecorne, A., Pelon, J., Ravetta, F. & Keckhut, P. Stratospheric smoke with unprecedentedly high backscatter observed by lidars above southern France. Geophysical Research Letters, 45, https://doi.org/10.1002/2017GL076763, 2018.

Godin-Beekmann, S., Porteneuve, J., Garnier, A. : Systematic DIAL lidar monitoring of the stratospheric ozone vertical distribution at observatoire de haute-provence (43.92 N, 5.71 E). Journal of environmental Monitoring, 5(1), 57-67, 2003.

Instrument Description:

The off-line (Rayleigh-Mie) channel of LiO3S Stratospheric Ozone (DIAL) lidar features Nd:YAG laser frequency-tripled to 355 nm, which operates at 50 Hz pulse rate and 42 mJ/pulse energy. The total collective surface of its mosaic 4-mirror telescope is 0.88 m2. The maximum vertical resolution of the lidar amounts to 15 m, however the vertical profiles are usually reported at 150 m resolution. Beam expanders are used to reduce the divergence 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. The laser beam is 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 µs. The elastically backscattered signal at 355 nm is 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. Optical signal detection is made by Hamamatsu photomultiplier tubes running on a counting mode. Counting gating is 0.1 microsecond providing a 15 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.

Algorithm Description:

For retrieving vertical profiles of stratospheric aerosol we use LiO3S measurements since 1994 conducted with an average monthly rate of 12 acquisitions per month, lasting 3-5 hours each. The retrieval is based on the Fernald-Klett inversion method (Fernald, 1984; Klett, 1985), which provides backscatter and extinction coefficients. The scattering ratio (SR) is computed as a ratio of total (molecular plus aerosol backscattering) to molecular backscattering. The reference zero-aerosol altitude is set between 30 and 33 km. LiO3S 355 nm data are converted to 532 nm using wavelength exponents for particle extinction (κe) and backscatter (κb) adapted from Jäger and Deshler (2002; 2003) and set to κe=1.6 and κb=1.3 after the year 1997. Similarly, the extinction-to-backscatter (lidar) ratio is set to 50 sr after 1997, which is a commonly assumed value for volcanically-quiescent conditions and periods of moderate eruptions (e.g. Trickl et al., 2013; Ridley et al., 2014; Sakai et al., 2016). The molecular backscatter is calculated from National Centers for Environmental Prediction (NCEP) daily meteorological data interpolated to OHP location. The lidar raw signals are subjected to a thorough quality screening, accounting for the instruments' technical health log. The overall rejection rate amounts to 17%. The aerosol retrieval is detailed by Khaykin et al. (2017).

Expected Precision/Accuracy of Instrument:

Cumulative uncertainties of the backscatter measurements induced by random detection processes, possible presence of aerosol at the reference altitude and the error in lidar ratio value do not exceed 7% as reported by Chazette et al., (1995). Another major source of uncertainty is the molecular number density derived from atmospheric pressure and temperature. The lidar inversion is particularly sensitive to the molecular density at the reference altitude, where the lidar return is assumed to be purely due to molecular scattering. Since the routine radiosonde measurements, commonly used to derive the molecular density, rarely reach the reference altitudes above 30 km, reanalysis data are required for the inversion.

We compared the monthly-mean series of integrated backscatter coefficient in 17 - 30 km layer retrieved using NCEP and ERA-Interim reanalyses and found a mean relative difference of 5.6 % between both datasets. This value may serve as an estimate for the uncertainty due to molecular density. As a result, the total uncertainty of individual backscatter measurement is below 10 %. We note that the uncertainty in the assumed lidar ratio has a very limited effect on the derived values of backscatter coefficient and scattering ratio (~0.15 %/sr). At the same time, error in lidar ratio affects proportionally the aerosol extinction and optical depth, whose uncertainty may thus be somewhat larger

Instrument History:

Since the late seventies, a lidar system designed for stratospheric observations of ozone, temperature and aerosols was running at OHP. This old system was separated into an ozone lidar (LiO3S DIAL) and a Rayleigh-Mie lidar (LTA, temperature and aerosol) in 1981. For over three decades two independent lidar systems have been operated at OHP station: a Differential Absorption Lidar (DIAL) for stratospheric ozone (LiO3S) and a Rayleigh-Mie-Raman lidar (LTA) for middle atmosphere temperature measurements. Both LiO3S and LTA lidar systems provide routine measurements since 1985 and 1979 respectively. After a technical upgrade of both lidars in 1994 the mean measurement rate is 10-12 acquisition nights per month. The continuous stratospheric aerosol data record from LiO3S lidar at 355 nm is available at NDACC since January 1994.