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NDACC METAFILE
Dumont d'Urville Aerosol/PSC lidar

Data Set Description:

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Instrument: Backscatter Rayleigh-Mie-Raman lidar
Site: Antarctic Station
Dumont d'Urville (66S, 140E)
Measurement Quantities:
Stratospheric Aerosols and/or PSC profiles (8-32 km in average)

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Reference Articles:

Australian Black Summer smoke observed by lidar at the French Antarctic station Dumont d'Urville
Tence F., Jumelet J., Bekki S., Khaykin S., Sarkissian A., Keckhut P.
Journal of Geophysical Research: Atmospheres, American Geophysical Union, 2022, 127 (4), pp.e2021JD035349. ⟨10.1029/2021JD035349⟩

14 years of lidar measurements of Polar Stratospheric Clouds at the French Antarctic Station Dumont d'Urville
Tence F., Jumelet J., Bouillon M., Cugnet D., Bekki S., Safieddine S., Keckhut P., Sarkissian A.
Atmospheric Chemistry and Physics Discussions, European Geosciences Union, 2022, pp.(Discussions). ⟨10.5194/acp-2022-401⟩

The 2019/20 Australian wildfires generated a persistent smoke-charged vortex rising up to 35 km altitude
Khaykin S., Legras B., Bucci S., Sellitto P., Isaksen L., Tence F., Bekki S., Bourassa A., Rieger L., Zawada D., Jumelet J. et al., Springer Nature, 2020, 1, pp.22. ⟨10.1038/s43247-020-00022-5⟩

Detection of aerosols in Antarctica from long-range transport of the 2009 australian wildfires
Jumelet J., Klekociuk A. R., S. P. A., Bekki S., Hauchecorne A., Vernier J.-P., Fromm M., Keckhut P.
Journal of Geophysical Research: Atmospheres, American Geophysical Union, 2020, 125 (23), pp.e2020JD032542. ⟨10.1029/2020JD0325⟩

Antarctic ozone enhancement during the 2019 sudden stratospheric warming event
Safieddine S., Bouillon M., Paracho A., Jumelet J., Tence F., Pazmino A., Goutail F., Wespes C., Bekki S., Boynard A., Hadji-Lazaro J. et al.
Geophysical Research Letters, American Geophysical Union, 2020, 47 (14), pp.e2020GL087810. ⟨10.1029/2020GL087810⟩

David C., S. Bekki, N. Berdunov, M. Marchand and G. Mégie, Classification and scales of Antarctic Polar Stratospheric Clouds using wavelet decomposition, J. Atm. Solar-Terrestr. Physics, 67, 293-300, 2005.

David, C, S. Bekki, S. Godin, G. Mégie and M.P. Chipperfield, Polar Stratospheric Clouds climatology over Dumont d'Urville between 1989 and 1993 and the influence of volcanic aerosols on their formation, J. Geophys. Res., 103, 22,163-22,180, 1998.

Jumelet J., C. David, S. Bekki, and P. Keckhut, Uniwavelength lidar sensitivity to spherical aerosol microphysical properties for the interpretation of lagrangian stratospheric observations, J. of Atmos. and Solar-Terr. Phys., 71, 121-131, doi:10.1016/j., 2009.

Jumelet J., S. Bekki, C. David, and P. Keckhut, Statistical estimation of stratospheric particle size distribution by combining optical modelling and lidar scattering measurements, Atmos. Chem. Phys., 8, 1–14, 2008.

<u>Instrument Description:</u>

The aerosol/PSC lidar in Dumont d'Urville is a backscatter Rayleigh-Mie-Raman lidar designed to characterize particles in the upper troposphere and lower stratosphere, roughly between 8 and 32 km.

The aerosol/PSC lidar in its current state has 2 modes:

- One emitting with the pre-existing Quantel CFR source Nd:YAG – to be put into passive mode in 2023 for calibration tests and emergency spare
- One emitting with the 2022 installed Lumibird Q-Smart Nd:YAG source.
  From 2022 on the lidar is expected to primarily use this laser as emission system.

Here are the main characteristics of the instrument:
- Emitted wavelengths of 532 and 1064 nm (up to 2022) , 355nm, 532 and 1064nm from 2022. UV and IR channels are still to be validated for the reception part.

- Beam expander to get 0.5 mrad beam divergence
- 80 cm Newton telescope
- Mechanical chopper (cut signal between 0-5 km)
- First beam splitter:
  - UV wavelengths
  - Wavelength other than UV (for aerosol/PSC and temperature)
- Aerosols beam splitter box:
  - High 532 nm channel
  - Low 532 nm channel
  - 607 Raman channel

- 1064 Infrared channel

- Hamamatsu photomultipliers for 532 nm and 607 nm
- APD photodiode for 1064 nm
- Photo-counting mode at 532 nm and 608 nm (60 m vertical resolution, 2048 points)
- Analog mode at 1064 nm
- Aer/PSC and ozone electronical switch
- Lumibird & Embedded Devices electronic acquisition cards
- Arduino command cards for syncing Q-switch and chopper signal
- Labview, and proprietary acquisition software (updated 2012). Python algorithms interfacing.

Algorithm Description:

The algorithm has been redesigned in 2018. Preprocessing is done by checking consistency of the atmospheric scene by adapting lidar integration time, starting from the individual 3mn raw files and using an estimate of the 532nm attenuated backscatter ratio (SR). Background sky correction is done by calculation of the Signal-to-noise ratio in the 30-50 last km of the profile (max altitude at 120km).

Molecular scattering is calculated from combination of local radiosondes and NCEP extracted data above the station. Depending on the time of the year, sonde horizontal drift and vortex position, only NCEP reanalyzes may be used as uncertainties on the local temperature tend to be lower and consistency is improved over the year.

Elastic inversion is made from the Klett-Fernald solution, with iterative normalization to ensure proper particular extinction. Lidar ratio profile is attributed using the 532nm SR estimate combined to altitude/temperature to derive particle type estimate.

Inelastic inversion is available on some profiles depending on the quality of the signal-to-noise ratio. The 608nm N2 Raman channel is usually too low to be considered as support on an operational basis, depending on the tropospheric cloud cover and background sky conditions. Level 2 products are:

- Backscatter coefficient (km-1.sr-1) and backscatter ratio at 532 nm on the parallel polarization plane;
- Backscatter coefficient (km-1.sr-1) and backscatter ratio at 532 nm on the perpendicular polarization
- Total 532nm scattering ratio (#)
- 532nm Aerosol depolarization ratio (%)

Retrieval of the 355nm and 1064nm from the 2022 system is under calibration, required electronics has to be deployed on the station in the next seasons.

Expected precision / Accuracy of the instrument:

Jumelet et al., 2020 presents the recent uncertainty estimation

The SR uncertainty is first related to statistical fluctuations of the measured lidar signal with random detection processes estimated using a Poisson distribution from the number of photons received. It is around 2% on the parallel channel and below 5% on the perpendicular channel for significant layers, as increased backscatter leads to smaller uncertainty. Uncertainty on the Rayleigh contribution is estimated to be below 2%. For the lidar ratio, using the 607 nm N2 Raman as calibration decreases the overall uncertainty of around 20%. Using the 10 most recent years in the existing database as calibration, the total SR uncertainty is estimated to be around 7% on SR// up to 28 km. On the perpendicular channel, the signal has a lower SNR, leading to a greater uncertainty on the clear-air reference taken above 25 km. The retrieval procedure leads to an altitude-dependent uncertainty ranging from 10% to 30%, also depending on the lidar integration time. Depolarizing material generates higher perpendicular backscatter coefficients, resulting in higher SNRs and therefore lower uncertainties. We statistically estimate the uncertainty on SR⊥ around 20%. Overall, The total 532 nm SR is calculated from the parallel and perpendicular backscatter ratio accounting for the influence of the molecular depolarization ratio (0.44% from our system specs). Using the averaged SR values presented in this paper as a reference and considering the above uncertainties on both SR// and SR⊥, the total uncertainty on the scattering ratio is therefore estimated at around 30% for profiles determined on integration windows of less than 1h30, and 20% beyond 2h time integration.

<u>Instrument History:</u>

Since 1989, France leads a monitoring program on human impacts on the Antarctic polar stratosphere. A set of instruments designed to measure ozone and parameters linked to its chemical equilibrium, were implemented on the French Antarctic base, Dumont d'Urville. The French Polar Institute (IPEV – Institut Polaire Français Paul-Emile Victor) supplies recurrent funding and logistics. In this frame, ground-based lidar aerosol and PSC observations were first conducted within the POLE (Polar Ozone Experiment), a French-Italian collaboration between the Service d'Aéronomie-IPSL and the IROE-CNR. In 1989, a backscatter lidar to measure stratospheric particles was implemented. In 1991, this lidar became a multi-wavelength system allowing sequential observations of the vertical distribution of ozone and stratospheric particles. Failures of this out of date instrument forced to completely stop ozone measurement in 2000. Stratospheric particles observations continued, but were almost unexploitable.

A new instrument was then studied, since 2002, within a new French-Italian collaboration between LATMOS-IPSL (formerly Service d'Aéronomie, change in 2009) and ISAC-CNR. This new lidar system in Dumont d'Urville includes the upgrade of the aerosol/PSC lidar, of the ozone lidar. Field implementation started in 2005 for a one year test. Stratospheric particles and temperature measurement are operational since 2006. Ozone measurements only started in 2008, due various hardware failures.

Starting 2012, regular failures on the ozone system and drastic increase of the Xe-Cl gas cartridges lead to the decision to stop the ozone lidar mode to fully focus monitoring time on the R/M/R aerosol lidar as ozone is still monitored by SAOZ spectrometer and local O3 sondes.

The reception electronics has been completely overhauled in 2012 from the photomultipliers to the acquisition cards and software. From this point on no major failure leading to data loss than 4 months has appeared. In 2016, critical hardware failure within the laser source was patched on site and the laser was brought back to France for upkeep in 2017.

Considering the ever increasing occurrence of fine aerosol plumes coming from the lower latitude combined to the major scientific interest on monitoring stratospheric aerosol plumes (from volcanic and pyroconvection origins), we decided to extend the system capabilities starting with a new laser source able to simultaneously emit in the UV, Vis, IR wavelengths. Such emissions actually may provide access to characterization at a lower level than optical properties: parameters of the particle size distribution may be derived and the retrieval methodology is already available at LATMOS.

In 2022, a new laser source Lumibird Qsmart has therefore been deployed on the station to replace in the near future the aged CFR laser. The additional channels are still under calibration. In 2022 monitoring time was split between CFR and QSMART for calibration purposes. From 2022 and onwards, the new system is expected to be fully operational.

Chronology of instrument running:
1988
Field implementation of Rayleigh/Mie aerosol/PSC lidar
Start of NDACC validated data
1989
Rayleigh/Mie aerosol/PSC lidar operational
1998
Instrument becomes old and degraded
Last year of NDACC validated data
2002
Study of a new instrument
2005
Field implementation of the lidar system named LOANA
2006
LOANA Rayleigh/Mie aerosol/PSC lidar operational
Start of NDACC validated data
2012
Electronics overhaul
2013
Ozone lidar stopped and dismantled
2017
Lidar maintenance during summer campaign after hardware failure in 2016
2020
Synchronization system redesigned
2022
Laser source renewed and deployed on field
From the significant changes since 2012, instrument is renamed as Liraan
(translated from french: ANtarctic Atmosphere Research LIdar).