Automatic Lidar and Ceilometer Framework (ALCF)

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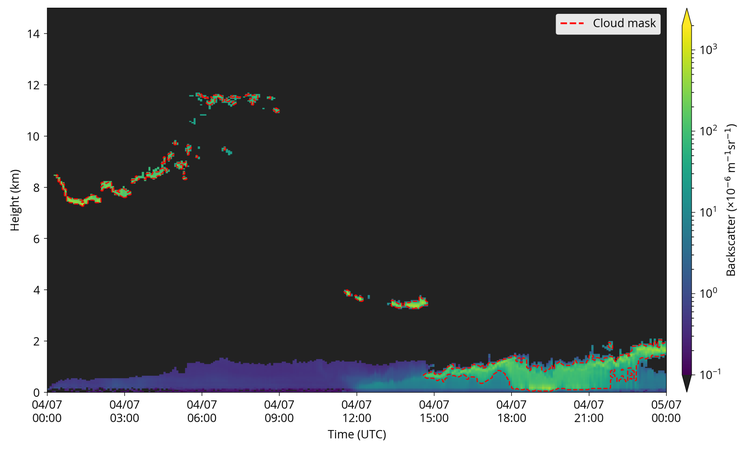
- **What?** ALCF is an open source lidar processing tool and a lidar simulator written in Python and Fortran.
- **Why?** A large number of automatic lidar and ceilometers (ALC) are deployed worldwide, but there is a lack of open tools for processing lidar data and comparison with general circulation models (GCM) and numerical weather prediction (NWP) models.
- **How?** ALCF processes data from lidars and runs a lidar simulator on model atmospheric fields to enable 1:1 comparison between observations and the model.

Features:lidar simulation, absolute calibration, noise removal, resampling, cloud detection, statistics, plotting

Available at
alcf-lidar.github.io



ALCs

ALCs are ground-based lidars operating by sending pulses of laser radiation in the near-infrared or visible spectrum and measuring received radiation. ALCs can measure cloud base, cloud layers, cloud phase, backscatter, boundary layer height and aerosol concentration. Closed firmware processing of raw signal hinders comparison between instruments, GCMs and NWP models.

Lufft CHM 15k

Lufft CHM 15k is a near-infrared (1064 nm) ceilometer with a range of 15 km.

Vaisala CL51 and CL31

Vaisala CL51 (CL31) is a near-infrared (910 nm) ceilometer with a range of 15 km (7.6 km).

Sigma Space MiniMPL

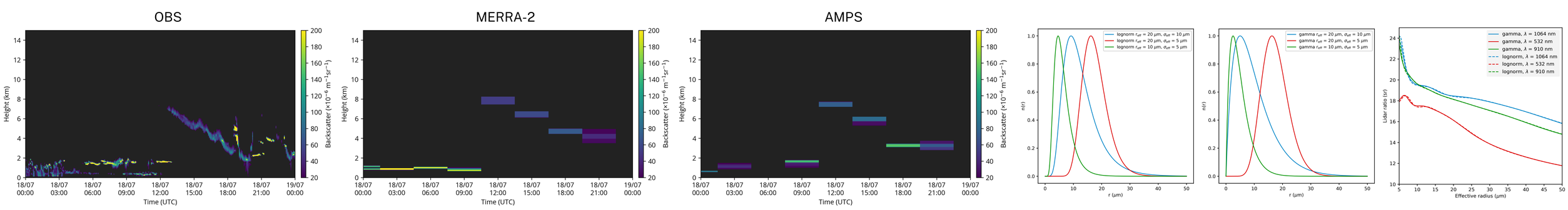
MiniMPL is a visible spectrum (532 nm) dual-polarisation lidar with a range of 30 km.

Model evaluation using ALCs

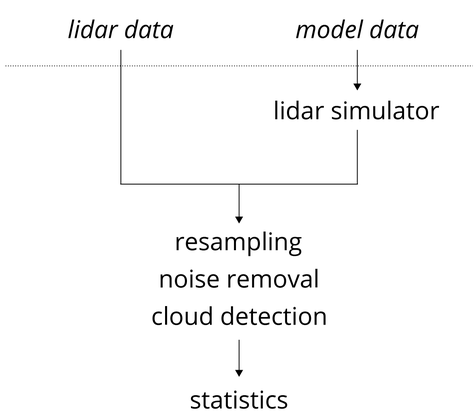
Model cloud fields can be compared to cloud measured by ALCs. Due to strong laser signal attenuation in thick clouds, a lidar simulator has to be used to achieve 1:1 comparison with model fields. The COSP simulator suite has been used for the past decade with the space lidar CALIPSO, with no equivalent available for ground-based lidars. ALCF extends and integrates the lidar simulator in COSP with additional processing to allow for easy 1:1 comparison with off-the-shelf ALCs. The simulator transforms model cloud liquid (clw) and ice (cli) fields to backscatter profiles. The simulator works "offline" on model output in NetCDF in standard format such as the CMIP5 format. The same post-processing steps are applied on measured and simulated backscatter.

Mie scattering

The laser radiation interacts with cloud droplets and ice crystals via Mie scattering, which depends on the laser wavelength and particle size distribution. We have modified the lidar simulator in COSP to account for different ALC lidar wavelengths by calculating the expected lidar ratio as a function of the effective radius of particles using the MIEV Mie scattering code.



Lidar data processing



Noise removal

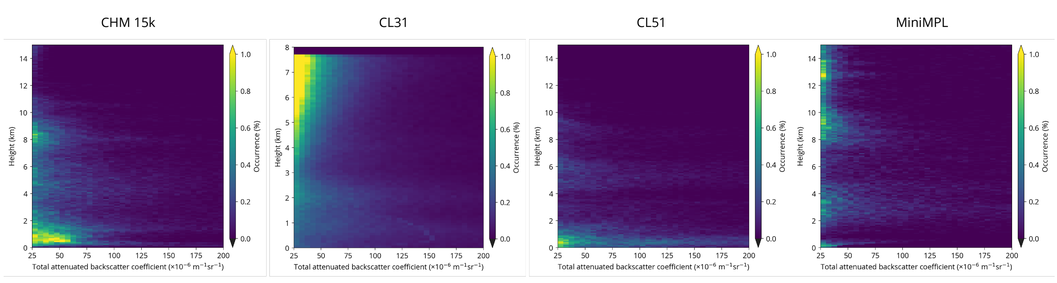
Lidar backscatter is affected by noise which scales with the square of range. Noise can obscure thin cloud above approx. 4 km in some instruments. ALCF removes noise by estimating noise distribution mean and standard deviation.

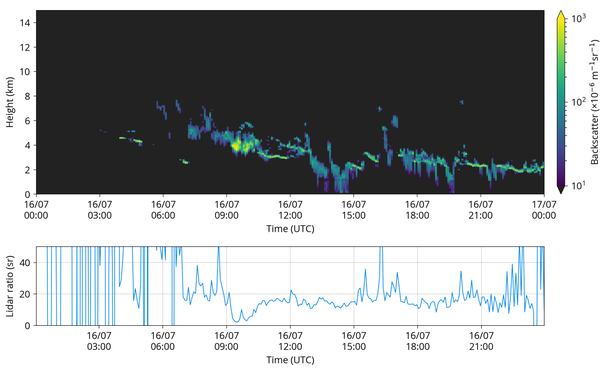
Cloud detection

Cloud detection in ALCF is performed by applying a n-sigma (3-sigma by default) threshold on the backscatter. This way false detection is avoided and comparison with models can be unbiased. Models do not repreduce vertical gradients of backscatter well due to low resolution. Absolute threshold based comparison is most likely to work comparably across models and observations.

Absolute calibration

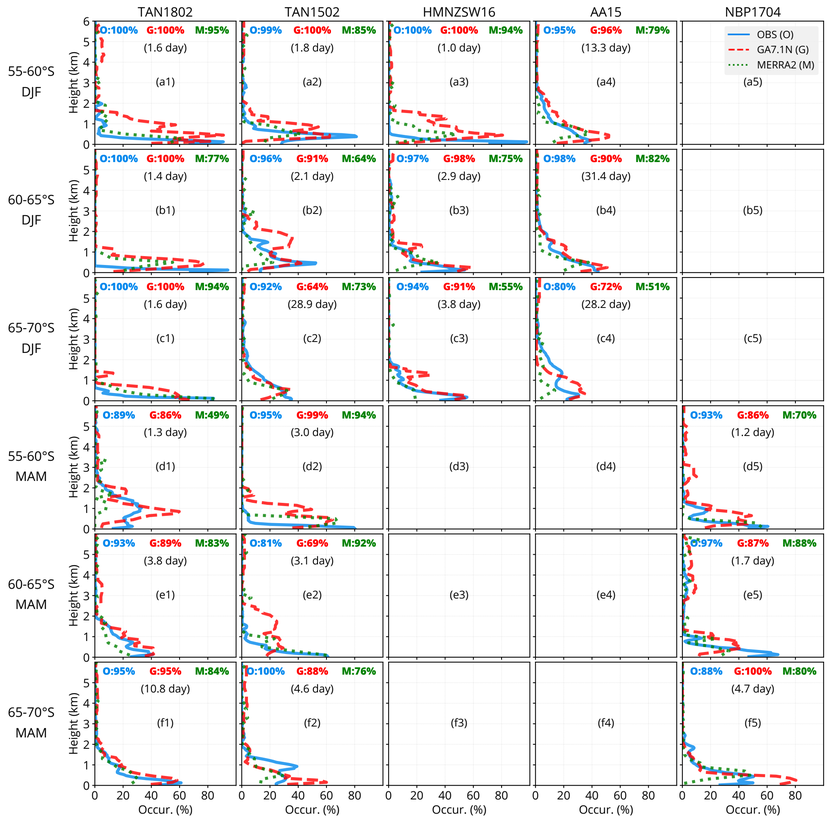
Absolute calibration can be performed using the vertically integrated backscatter method in thick stratocumulus clouds, which is equal to a known value of lidar ratio. ALCF can plot this value along backscatter profiles, which allows instrument absolute calibration factor to be determined.





Case study: Southern Ocean model cloud evaluation

We have used ALCF for Southern Ocean cloud evaluation in the HadGEM3 GCM and MERRA-2 reanalysis (Kuma et al., 2019). We compared the models with ship observations collected over 4 years. ALCF was used to compare vertical cloud occurrence and the total cloud cover between the Lufft CHM 15k and Vaisala CL51 observations and models. Thanks to this approach we found that the models underestimate low cloud below 500 m and fog and the total cloud cover is underestimated by up to 18%.



Acknowledgments

The ALCF lidar simulator is based on a lidar simulator of the COSP project provided under a BSD license.