European networks observing the atmospheric boundary layer: Overview, access and impacts

Chapter: Automatic lidars and ceilometers (ALC)

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Introduction

This report provides a short overview of operating automatic lidars and ceilometers, including introduction to sensor, products, manufacturers, instrument types, instrument setup and required regular maintance on site, calibration, measurement configuration, data formats, QA/QC methods and retrieval methods.

Part 1 General overview

<u>Introduction</u>
Automatic lidars and ceilometers (ALC) are low-maintenance lidars (Section 1.3), usually operating on a single wavelength (but some dual-wavelength ALC are available). A transmitter emits eye-safe laser pulses into the atmosphere, the back-scattered light is captured by a receiver. From the round-trip time, a profile of the range-corrected signal can be obtained which represents the (commonly uncalibrated) attenuated backscatter. Some ALC include a depolarisation channel. In contrast to high-power lidars that are often subject to intermittent schedule operation and research environment settings, ALC can be operated continuously with very little maintenance.

<u>Products</u>
Two main products are provided by ALC: The profile of attenuated backscatter and the cloud base altitude. The cloud base altitude is derived from attenuated backscatter observations by the proprietary instrument firmware. Some ALC provide heights of multiple cloud layers at a time and cloud cover products are also available.

Higher level products that can be obtained from these observations include cloud type, detection of precipitation and hygroscopic particle growth (fog formation), heights of the atmospheric boundary layer, or aerosol products (e.g. backscatter coefficient). Some manufacturers include atmospheric boundary layer height products in the output from ALC, with fog alerts or precipitation products being under development. Some manufacturers also provide detailed aerosol products (such as depol ratio or aerosol mass concentration).

<u>Manufacturers/Instrument types</u>
Most ALC report the following "standard products": attenuated backscatter, cloud base height, atmospheric boundary layer height (ABLH). (For ABLH from Vaisala sensors, a specific software license (*BLview*) is required to replace standard data acquisition with *CLview*.)

Manufacturer	Model	Wavelength	Max range*	Min resolu-tions	Power	Other products	Blind zone**
Lufft – Ott Hy-dromet	CHM15k	1064 nm	15 km		50mW	Cloud top	~240 m
	CHM8k	905 nm	8-10 km			Cloud top	
Vaisala	CL61	910.55 nm	15.4 km	4.8 m, 5 s	30mW	Depol, vertical visibility for very low cloud base	40 m
	CL51	910 nm	15 km	10 m, 6 s	19.5 mW	vertical visibility for very low cloud base	50 m
	CL31	910 nm	7.6 km	5 m, 2 s	12 mW		10 m
Raymetrics	RAP	1064 nm	>14 km	12 s, 3.5 m	150 mW	(Depol	250 m

			(depol. ~up to 3-4 km)			under testing)	
Droplet MT	MiniMPL	532 nm	> 15 km	5 m, 1 s	10 mW	Depol, Depol ratio, Particle type, Cloud top, Cloud peak, Total extinction, Aerosol mass concentration, AOD	0 m
Cimel	CE376	532 nm / 808 nm	15 km / 7 km	7.5 m, 0.8 s	35 mW / 15 mW	PBL, Cloud top height, Depol, Color ratio	420 m / 250 m
Campbel Scientific	SkyVUE	912 nm	8-10 km	5 m			

* As stated by manufacturer.
** The Instrument blind zone due to incomplete optical overlap is here defined as the distance from the sensor where corrected optical overlap is below 5% (Poltera et al. 2017)[1].

Additional model-specific information:

- Cimel, Lufft CHM15k and Droplet MT MiniMPL use photon counting technology.
- Raymetrics RAP works with diode pumped solid state Nd: YAG laser and analogue detector.
- CIMEL work with both laser and laser diode.
- Vaisala and Lufft CHM8k work with laser diode and analogue detector.
- Raymetrics Aerosol Profiler (RAP) has built-in “dark measurement“ capability, as well as Telecover test and motorized telescope/laser field of view alignment.

Droplet MT MiniMPL has 2 versions reporting up from 50 m or 100 m minimum range, respectively. MiniMPL has possibility to add scanner for multiple, programmable view angles. MiniMPL has “normalized relative backscatter” product which uses key instrument calibrations to remove instrument-to-instrument variations between units.

Part 2 Practical considerations

<u>Instrument setup</u>

ALC need to be installed on a secure, stable, levelled-surface (e.g. concrete base). Open view to the sky (e.g. no tree branches) is mandatory. Although ALC operate eye-safe lasers that do not require specific security clearance in most cases, regulations applicable for the specific measurement location should be checked.

<u>Required regular maintenance on site</u>

Clean window when window condition reported by the housekeeping data is less than ideal. Frequency depends on measurement location and pollution in the probed atmosphere.

<u>Calibration</u>

No on-site calibration is required. The reported range-corrected signal after application of the optical overlap correction can be considered to represent the uncalibrated attenuated backscatter. To derive the absolute value of attenuated backscatter (e.g. required for aerosol studies), two methods for calibration during post-processing are available: the “cloud calibration method” (Hopkin et al., 2019[2]; O’Connor et al., 2004[3]) and the “Rayleigh calibration method” (e.g. Wiegner and Geiß, 2012[4]). Both are utilising the probed atmosphere and some assumptions to determine a calibration coefficient.

NOTE: Campbell Sci SkyVUE series has a build-in cloud calibration option for on-site absolute calibration.
NOTE: Vaisala CL61 attenuated backscatter profile is cloud calibrated at factory by O'Conner et al.[3] method. Also on-site recalibration is possible. CL61 has also SI traceable calibration certificate for time-of-flight measurement.

<u>Measurement configuration</u>

Most ALC settings are specific to the manufacturer. Both ACTRIS and E-PROFILE recommend the following settings.

Vaisala

- See dedicated PROBE documents on operating guidelines for Vaisala CL31 and Vaisala CL51.

Lufft

- It is recommended to use the NetcdfMode (“set NetcdfMode = 2” when updating to firmware version >=1.05).
- Use of firmware version 1.07 is recommended, specifically versions 1.05 and 1.06 should be avoided.

Raymetrics

For participation in EARLINET as part of ACTRIS the following quality assurance tests are recommended:

- Automated Quality Assurance tests:
  - Automated dark signal measurements
  - Telecover test
- ACTRIS QA:
  - Zero-bin tests report
- Other:
  - Motorized alignment

In addition there are also several additional requirements in order to join EARLINET, which are summarized here: https://www.earlinet.org/index.php?id=268

Droplet MT

- SigmaMPL2015R2.3 or higher version of software is required.
- NETCDF data should be enabled and configured to send to a pre-determined network location. Set “netCDFFTP=1” in INI file. Enter in server details in SigmaMPL through the Configure->Real Time Setup->FTPNetwork->Add/Edit Server.
- Aeronet data should be configured to allow for AOD data to be ingested with the LiDAR data. This can be configured using the Configure->Algorithm Setup->Lidar Equation menu in SigmaMPL. The user has 2 ways to retrieve the Aeronet Data. 1) AOD Enclosure – Select this option and type in the Aeronet Site name as its listed on the Aeronet website to download the data directly from the Aeronet website. 2)

Proxy Server – Select this option and enter in the server details to get the data directly from a proxy server. Once the desired ingestion method is chosen, the user can choose between downloading Level 1 or Level 1.5 data and looking at AOD, SDA or both data products.

Cimel

The CIMEL CE376 GPN does not require specific conditions when used in its thermal enclosure. For use without a thermal enclosure, the temperature should lie between 23°C +/- 5°C to ensure the stability of the overlap function. For in room use with a window, special attention should be considered with the type and the size of the window to avoid any lens effect and depolarization.

Data formats

		Recommended by		**Accepted by**	
Manufacturer	Raw Format	E-PROFILE[1]	ACTRIS[2]	E-PROFILE	ACTRIS
Vaisala	CLview ascii (CL31, CL51)	x	x	x	x
	BLview ascii (CL31, CL51)			x	x
	BLview netCDF (CL61)	Soon	Soon	Soon	Soon
Lufft	ascii			x	x
	netcdf	x	x	x	x
Raymetrics	Raw data: text header + binary file				
	netcdf				
Droplet MT	Raw data (text header+binary file), .CSV netcdf	x	x	x	x
Cimel	Raw data: proprietary binary file Export data: ascii, png (netcdf)			x	x
Campbell Sci					

[1] E-PROFILE is part of the EUMETNET Composite Observing System, EUCOS, managing the European networks of e.g. ALC for the monitoring of vertical profiles aerosols including volcanic ash.
[2]ACTRIS is the fundamental European Research Infrastructure for short-lived atmospheric constituents including atmospheric profiling networks such as EARLINET.

QA/QC methods

- Monitor window transmission
- Monitor laser energy
- Monitor overlap temperature dependence (Lufft) (Hervo et al. 2016[5])
- Monitor instrument-related background (Vaisala) (Kotthaus et al. 2016[6])
- Vaisala CL61: instrument-specific functions for overlap correction provided by manufacturer
- For EARLINET (ACTRIS): monitor/adjust alignment with telecover test

Retrieval methods

- Unified cloud base height
- ABL heights (methods currently in evaluation)
- Aerosol products (methods in evaluation)

Part 3 References

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[1]Poltera, Y., Martucci, G., Collaud Coen, M., Hervo, M., Emmenegger, L., Henne, S., Brunner, D., and Haefele, A., 2017: PathfinderTURB: an automatic boundary layer algorithm. Development, validation and application to study the impact on in situ measurements at the Jungfraujoch, Atmos. Chem. Phys., 17, 10051–10070, https://doi.org/10.5194/acp-17-10051-2017.

[2] Hopkin, E., Illingworth, A. J., Charlton-Perez, C., Westbrook, C. D., and Ballard, S., 2019: A robust automated technique for operational calibration of ceilometers using the integrated backscatter from totally attenuating liquid clouds, Atmos. Meas. Tech., 12, 4131–4147, https://doi.org/10.5194/amt-12-4131-2019.

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[6] Kotthaus, S. et al., 2016: Recommendations for processing atmospheric attenuated backscatter profiles from Vaisala CL31 ceilometers, Atmospheric Measurement Techniques, 9(8), pp. 3769–3791. doi: 10.5194/amt-9-3769-2016