TO-PROF Automatic Lidar and Ceilometer Working Group (WG1)

WG Chair: Martial Haeffelin, IPSL; WG Co-Chair: Ina Mattis, DWD
Updated 2015-02-25

Introduction

Currently, several hundred laser-ceilometers are in operation over Europe, several thousands over the World. Each instrument emits a pulse of laser light and then detects the backscattered signal. Originally, as the name suggests, such instruments were designed for detecting the cloud base or "ceiling", but new Automatic Lidars and more sensitive Ceilometers (ALCs) provide high-resolution profiles of backscatter, from which vertically resolved aerosol and cloud properties can be characterized. Quite a variety of ALCs are deployed over Europe and the World and it is important that the backscatter profiles are derived in a manner that is well understood and documented.

Two programs in Europe are concerned with this question.

- E-PROFILE, a program of EUMETNET, focusing on harmonizing ALC measurements and data provision across Europe
- TO-PROF, a COST action oft he European Commission, that aims at better characterizing the parameters that can be derived from ALC measurement and related uncertainties.

E-PROFILE is interested particularly in ALC calibration, retrieval of attenuated backscatter profiles and cloud base height. TO-PROF supports E-PROFILE objectives by developing applications that could be implemented by E-PROFILE. Beyond these objectives, TO-PROF explores ALC capabilities and uncertainties to derive aerosol properties, boundary layer height, and fog prediction.

End-Users

Identified End-User communities of ALC's and parameters of interest are:

- National weather services (incl. COPERNICUS/MACC): calibrated attenuated backscatter profiles to evaluate NWP models (through forward operators); Cloud base height for NWP evaluation and weather monitoring.
- Agencies in charge of atmospheric surveillance for air traffic: occurrence, height and mass concentrations of ash layers; diagnostic and short-term forecast of fog and other low visibility events.
- Agencies in charge of Air Quality monitoring: boundary layer height; free-tropospheric aerosol transport.

- Networks in charge of GHG monitoring: boundary layer height to quantify GHG dilution effects.
- EUMETSAT: European-wide validation of cloud-base height and fog
- Renewable energy industry: Photovoltaic ReN - cloud/fog fraction and evolution for nowcasting applications (combined with geostationary satellite); Concentrated solar power: aerosol vertical distribution; Wind ReN – wind profiles from Doppler Lidars.

	Calib atten Backscatter	Cloud base height	Aerosol heights and properties	Boundary layer heights	Fog nowcasting	Other
NWP forecast	X	X		X		
Air traffic			X		X	
Air Quality	X		X	X		
GHG				X		
Satellite validation		X				
Renewable energy		X	X		X	
Other						

E-PROFILE and TO-PROF pursue a common goal to better characterize the performance of existing ALCs provided by a variety of manufacturers. The following instrument features are of interest to ALC users and should be investigated:

- Performance and sensitivity of ALCs during the day and night (for aerosol and cloud targets in particular).
- Short-term and long-term stabilities and drifts.
- Checking the operation of any automatic gain control system in ALCs.
- Characterization and correction for beam overlap effects at low altitudes.
- Absolute calibration of the ceilometer backscatter based on different methods and calibration stability.
- Calibration of depolarization ratio for ceilometers that provide cross-polar profiles.
- Performance in rain.

TO-PROF ALC WG Objectives

To support the implementation of a harmonized ALC network reporting quality-controlled calibrated attenuated backscatter profiles of aerosols and clouds in near real time across Europe.

To evaluate the backscatter profiles predicted by the prognostic aerosol schemes within the next generation of European forecast models for forecasting air quality as exemplified by the EU-FP7 MACC model at ECMWF.

To set up a system to monitor the spatial distribution, height and density of aerosol plumes (e.g. volcanic ash, mineral dust, biomass burning, or industrial accidents) over Europe, which are key information for air traffic safety, and to monitor the depth through which surface emitted species are mixed or trapped over Europe, a key factor for pollutant concentration predictions.

TO-PROF ALC WG Tasks

To tackle these multiple goals, TO-PROF WG1 put together 7 complementary Tasks:

- Task 1. ALC calibration
- Task 2. Data formats, target classification including cloud base height
- Task 3. Calibrated attenuated backscatter profiles for model evaluation and data assimilation
- Task 4. Aerosol property retrievals and uncertainties
- Task 5. Boundary layer retrievals
- Task 6. Fog prediction
- Task 7. Instrument intercomparison and characterization campaign

TASK 1: ALC calibration

Report 1, January 2015

By Frank Wagner, DWD Hohenpeißenberg

Objectives

Automatic lidars and ceilometers (ALCs) are designed for unattended and operational use. The main objective of this task is the development of a software code which performs automatically an absolute calibration, i.e. the determination of the system (lidar) constant including its uncertainty.

Tasks

1. Development of Software Code
   a. Development of a Matlab code which performs the so-called Rayleigh calibration
   b. Development of a Matlab code which performs the so-called liquid water cloud calibration
2. Development of a correction scheme for water vapor
3. Test and Modification
   a. Intensive tests of (1a) and modify software code by code developer
   b. Intensive tests of (1b) and modify software code by code developer
   c. Implement the scheme of 2 in 1a and 1b.
4. Combination of different software codes into one code

   This involves the combination of Rayleigh and liquid cloud calibration method into one code as well as the testing of the whole processing chain of WG1 (from raw data to calibrated data to final data)
5. Extensive testing of the code developed in (4) by the community and modifying/upgrading the code and removing of bugs

Milestones

M1	Development of Software Code	October 2014	Done
M2	Development of a correction scheme for water vapor	April 2015	
M3	Test and Modification of Rayleigh and liquid water cloud calibration	April 2015	
M4	Implementation of water vapor correction scheme in software code	Summer 2015	
M5	Combination of different software codes into one code	Autumn 2015	

SWGs and STSMs

STSM Oct 2014: First test of Rayleigh and liquid water cloud calibration
STSM April/May 2015: on water vapor correction schemes for ALC
SWG Summer 2015

Participants

- Frank Wagner, DWD Hohenpeißenberg
- Maxime Hervo, Meteo Swiss
- Ina Mattis, DWD Hohenpeißenberg
- Matthias Wiegner, Munich University
- Mariana Adam, Metoffice
- Quentin Laffineur, RMI

TASK 2. TARGET CLASSIFICATION

OBJECTIVES: deliver for common NetCDF format production; test code to perform target classification and evaluate CBH.

Participants: Martial Haeffelin, Marc-Antoine Drouin (IPSL); Alberto Cazorla (UGR) ; Matthias Wiegner (LMU)

MILESTONES:

- RAW2L1 code presented to E-PROFILE (October 2014; Marc-Antoine Drouin)
- Intercomparisons of Cloud Base Height retrievals (Alberto Cazorla (UGR))
-

DELIVERABLES:

- RAW2L1 code delivered to E-PROFILE (spring 2015)
-

Processing chain:

- Raw2L1, Preprocessor, Calibrator
- STRAT + specific needs: Marc-Antoine
- Comparison of STRAT with LMU code: Matthias
- Check LOA code BASIC: Matthieu

STSM: Not yet planned

SWG: Not yet planned

TASK 3. Calibrated Attenuated Backscatter

Mariana Adam, UK Met Office, 25/02/2015

Content

Objectives

Deliver attenuated backscatter and its error for Jenoptik CHM, Vaisala CT25, CL31, CL51, LD40 and Leosphere
Deliver historical detaset (Aug-Dec 2012) to WG4

Task participants

UK Met Office (Mariana): provide data for Jenoptik, Vaisala CT25 and CL31 (research mode); develop matlab code
Meteo Swiss (Maxime): provide calibrated data for Leosphere and LD40
RMI (Quentin): provide data for CL51
DWD (Ina and Frank): provide data for Jenoptik (firmware 0.7x)
IPSL/LMD (Martial) to provide data for CL31 (operational mode)
Note: Need data for Vaisala CT25 (operational mode). Do we still consider CT25 since they will be out of support next year?

Tasks

Collect data for testing for each instrument. Calibration constant (from Task 1) and overlap correction function (where available) should be provided.
Code to compute attenuated backscatter and its error for all instruments
Compute SNR as well
Run code for each instrument
Comparison ALC-Earlinet?
UKMO: comparison Jenoptik, Vaisala CL31 and UV Raman Lidar (possible to bring a Campbel Scientific - Mike Brettle)
Research on other types of errors (systematic)
Correction for Vaisala CT25 and CL31 research mode
Water vapor correction for Vaisala (input from STSM on H2O correction, LMU, end Spring 2015)

Milestones

Deliver codes to compute attenuated backscatter for each type of instrument
Attenuated backscatter results for each instrument
Error (SNR) characterization for each instrument

Deliverables

- Matlab code to compute attenuated backscatter and its error (for each type of instrument)
- Supporting documents for codes (step by step description of the algorithms)
- Summary of the data analyzed, including SNR
- Dataset of attenuated backscatter and its error for WG4

SWG and STSM

SWG (as proposed in Roskilde): Task 1, 2 and 3 – code implementation - Summer 2015, Paris

Summary of current results

Matlab code developed to compute attenuated backscatter for Jenoptik, Vaisala CT25 and CL31 (research mode), Vaisala CL51. No water vapor correction implemented for Vaisala.
Examples shown in Roskilde
Error comparison for a Jenoptik dataset by using two different methods
"Photon counting" instruments: use error propagation
"Analog" instruments: use error of the mean
Vaisala CT25 and CL31 in research mode need correction. Correction shown in Roskilde.

Ongoing/remaining tasks

Data collection for Vaisala CT25 and CL31 operational mode
Data collection for LD40 and Leosphere (Meteo Swiss)
Shift correction for Vaisala CT25 and CL31 research mode? Need Vaisala's input.
Water vapor correction to be implemented for Vaisala after STSM meeting at LMU.

TASK 4: Retrieval of Aerosol properties

Gian Paolo Gobbi (CNR) and Federico Angelini (ENEA)

Task Objectives:

Generation of functional relationships/look-up tables to estimate (continental, marine and mineral) aerosol physical properties (extinction, surface area and volume plus uncertainties) from aerosol backscatter profiles via the approach developed by Barnaba et al., (2001, 2002, 2004), and taking into account the current literature.

Task Work-plan (milestones) up to Granada 2015:

- November 2014: Constitution of a documentation database on Lidar-retrieval of Aerosol Properties;

- December 2014: Update and translate into Matlab the codes developed by Barnaba et al., (2001 and following).

- January 2015: Test the new code outcomes against published results (355 and 532 nm);

- February 2015: Implement the 1064 nm routines

- In March-April 2015 share/discussion with participants the relationships with the aim of testing them on 1064 nm ceilometer profiles and assessing their performances against "reference" measurements as of Raman lidars or sunphotometer AOT (this in the case of backscatter vs. extinction relationships). Being more complex, validation of surface area and volume retrievals (e.g., Gobbi et al., 2003) will follow later.
Since a SWG is not possible this year, collaboration will mostly take place via internet and by meeting in Granada.

- May 2015, Present/discuss relevant results at the meeting in Granada.

- Until End of 2015: Operational testing and interactive optimization of the algorithms.

References

- Barnaba F. and Gobbi. G.P., " Lidar estimation of tropospheric aerosol extinction, surface area and volume: Maritime and desert-dust cases", Journal of Geophysical Research, 106-D3, 3005-3018, 2001 (corrections in Barnaba and Gobbi, JGR, 107, D13, 10.1029/2002JD002340, 2002).

- Barnaba F. and G.P. Gobbi; Modeling the aerosol extinction versus backscatter relationship in a mixed maritime-continental atmosphere: Lidar application and validation, J. Atmos. Ocean. Technol., 21, 428-442, 2004a.

- Barnaba, F., F. De Tomasi, G. P. Gobbi, M. R. Perrone, and A. Tafuro, Extinction versus backscatter relationships for lidar applications at 351 nm: maritime and desert aerosol simulations and comparison with observations, Atmospheric Research, 70, 229–259, 2004b.

Participants who declared their interest in the Task as proposed by the e-mail below:

"Adam, Mariana" mariana.adam@metoffice.gov.uk, , Maxime Hervo <maxime.hervo@meteoswiss.ch>, Martial Haeffelin <martial.haeffelin@lmd.polytechnique.fr>, Angelini Federico <federico.angelini@enea.it>, GianPaolo Gobbi <g.gobbi@isac.cnr.it>

Withdrawn: matthieu sorel <matthieu.sorel@meteo.fr>

TASK 5. BOUNDARY LAYER RETRIEVALS

OBJECTIVES: Derive improved mixing height retrievals from large ALC networks. Advance in aerosol tracer understanding through combined analyses with Doppler Lidars (w variance) and Microwave Radiometers (T)
LEAD: Juan-Luis; Maria Joao

MILESTONES:

M1. *Definition of terminology related to PBL* (linked to tasks in E-PROFILE and ACTRIS).

Task1.1. Maybe we should contact Martucci (E-PROFILE) and Fabio Madonna from CNR-IMAA (ACTRIS) before the meeting in Denmark

Task1.2. Elaborate common terminology

M2. *State-of-the-art in PBL methodology*

Taking as starting point the review given by Petra Seibert et al. (Atmos. Environ. 34, 1001-1027, 2000) and the COST Action 710, a review of different PBL retrieval algorithms for ALC, MWR, Doppler and radiosounding will be done. Experimental approaches to derive PBL height using aerosol and meteorological tracers (for aerosol tracer: gradient method, logarithm gradient method, inflection point method, wavelet method based on different functions [Haar, Mexican hat, Gaussian], for meteorological tracers: temperature, potential temperature, wind) …

Task2.1. Review of published articles.

Task2.2. Write article.

M3. *Implementation of PBL-retrieving codes*

Need to establish data format and to implement standard codes

Task3.1. Establish a subgroup for implementing codes (voluntiers??)

Task3.2. Implementation of codes

Task3.3. Write documentation

M4. *Establishing a database for testing PBL-retrieving codes*

Task4.1. Select stations available to provide simultaneous data from ALC+MWR+Doppler+radiosounding or at least 3 of them to determine the best/worst instruments/methods (contributors?)

Task4.2. Establish periods (day/night, different seasons, …) using the existing database in each station

Task4.3. Design a strategy for simultaneous exercises (periods?)

M5. *Evaluation of methodologies*

Task5. Existing databases and/or new created databases will be used to evaluate the different methodologies

DELIVERABLES:

D1. Documentation terminology related to PBL (linked to tasks in E-PROFILE and ACTRIS) (likely as internal document?)

D2. Documentation on state-of-the-art in PBL height determination (article to be published?)

D3. Documentation on data format and PBL-retrieving codes (language?)

D4.1. Report including list of available stations, available instruments and available periods of simultaneous measurements

D4.2. Documentation on strategy for simultaneous exercises

D5. Report on evaluation of different methodologies (article to be published?)

PROPOSED WORK PLAN:

Milestone	Task	Task Deadline	Deliverable	Deriverable Deadline	Contributors
M1	T1.1	Nov 2014	D1	March 2015	M. Joao, Juan Luis, people from E-PROFILE and ACTRIS
	T1.2	March 2015			
M2	T2.1	May 2015	D2	Dec 2015	All contributors to task BOUNDARY LAYER RETRIEVALS
	T2.2	Dec 2015			
M3	T3.1	March 2015	D3	March 2016	Subgroup to be determined
	T3.2	March 2016			
	T3.3	March 2016			
M4	T4.1	March 2015	D4.1	March 2015	
	T4.2	March 2015			
	T4.3	Oct 2015	D4.2	March 2015	
M5	T5	Dec 2016	D5	Dec 2016	All contributors to task BOUNDARY LAYER RETRIEVALS

STSM	Date	People and Action
STSM1	Jun 2015	Juan Luis (U. GRANADA → U. ÉVORA) to discuss on state-of-the-art of methodology and status of the article
STSM2	Sep 2015	subgroup to discuss about codes implementation. Place: to be determined
STSM3	July or Sep2016	M. Joao (U. ÉVORA → U. GRANADA) to discuss on report regarding evaluation of different methodologies

TASK 6: Use of ALCs for fog diagnostic and nowcasting

Task coordinators: Martial Haeffelin (IPSL), Quentin Laffineur (RMI)
Task participants: Ventsislav Danchovski (Sofia Univ.)

STSM in 2014
COST STSM Reference Number: COST-STSM-ES1303-21284
Period: 06/10/2014 to 10/10/2014
STSM Applicant: Dr Quentin Laffineur,Royal Meteorological Institute of Belgium,B-1180 Brussels(BE) , lquentin@meteo.be
STSM Topic: Use of ALC measurements to detect and predict fog events
Host: Dr Martial Haeffelin,Institut Pierre-Simon Lapalace,75252 Paris Cedex 05(FR), martial.haeffelin@ipsl.polytechnique.fr

1. **Introduction**

Some ALCs have nominal optical overlap at very low range gate, which is useful in analysing the backscatter signal in the boundary layer to monitor the first formation stage of the fog that potentially contains major information to predict fog formation or not. We know that during the preliminary stage of fog formation, the backscatter profile may be influenced by atmospheric humidity due to the presence in the atmosphere of hygroscopic aerosols that see their size increase with their moisture content inducing an increase of the backscatter magnitude.

2. **Objectives**

The development of a forward stepwise screening algorithm to help prediction of radiation fog formation and transitions between stratus and fog based on the hygroscopic growth function of aerosol scattering coefficient (Yan et al. 2009) coupled with the standard surface weather observations.

3. **Summary of results in 2014**

Within the STSM, promising lines of work were elaborated and explored for the task 6. A methodology was developed to select appropriate fog predictor parameters based on the backscatter signal (not calibrated) and on the measurements of atmospheric parameters of an automatic weather station. In a first step, the analysis focused especially on the “elevated” radiative fog whose the primarily stages of their formation can be detected in the backscatter signal of the ALC before that the visibility at the surface was significantly impacted.
A selection of 6 radiative fog events and 3 radiative quasi-fog events observed during the the ParisFog field experiment campaign was analysed. This separation between fog and quasi-fog events was necessary in the analysis to highlight potential indicator thresholds in the backscatter signal make it possible to predict fog development or not.
For each fog events, the time position of the minimum value of the relative humidity measured at 20 and 30 m was sought between the fog formation and 10 hours before. From this minimum up to the fog formation, the ratio between the backscatter signal (Pr^2) at 22.5m (closest to 20m), at 37.5m (closest to 30m) and the backscatter measured (22.5 and 37.5 m) when the humidity was minimum (Pr^2(ref)) was computed.

The figure 1 shown the relationship between the backscatter ratio (at 22.5 and 37.5 m) and the relative humidity for the radiative fog events studied. In some cases, an exponential increase in the backscatter ratio with the humidity was observed. In the case of radiative fogs, the increase started only after that humidity was higher than 90%. It was not the case for the radiative quasi-fogs (data not shown) where the increase started long below 90%. In all cases, this exponential behaviour was linked to the exponential increase in the hygroscopic aerosol size with the relative humidity. In the case where the absolute value of the backscatter was highest, no clear exponential increase was observed. The presence in the atmosphere of a high concentration of other kind of aerosols (responsible of the high backscatter observation) than hygroscopic may hide the observation of the hygroscopic aerosols behaviour with the humidity.

4. **Tasks for 2015**

- Extend the analysis to other "elevated" radiative fog and quasi fog events observed during the ParisFog campaign.
- Extend the analysis to other "elevated" radiative fog and quasi fog events occurred in other places (candidate: Uccle, Belgium) where ALC data and the standard surface weather observations are available.
- Identify the potential cases when the methodology predicts falsely radiative fog.
- Determine how far in advance aerosol activation process can be detected.

5. **Milestones**

- Write a paper describing the methodology and its robustness to predict the "elevated" radiative fog based on a statistical analysis of the ALC dataset of ParisFog campaign, the ALC dataset of Uccle and others ALC dataset where radiative fog and quasi-fog events are already identify.
- Write an automatic algorithm based on the methodology to compute a kind of "fog alarm index"
- Test in real-time the algorithm in parallel with the usual fog prediction methods used by a weather forecasting office.

TO-PROF COST action, WG1, Task 7 ALC performance experiment

Report 1, January 2015

By Ina Mattis, DWD Hohenpeißenberg

Objectives

The performance and behavior of the automatic lidars and ceilometers (ALCs) that are typically used in the E-PROFILE and TOPROF community shall be tested during a measurement campaign in Lindenberg, Germany in summer 2015. In order to allow for a fast organization and an open access to the obtained results, this experiment shall be performed mainly with instruments that are already owned by E-PROFILE and TOPROF partners. The main objectives are the quantitative comparison of backscatter profiles, signal-to-noise profiles and cloud data. Open data exchange among participants is necessary and results of the campaign shall be made public.

Tasks

1. Preparation of the campaign
    a. Contact and organization with participants who contribute with instruments (deadline for response of interested participants = end of February 2015)
    b. Support for shipments by EPROFILE?
2. Realization of the campaign, at Lindenberg, 3 months (June-August 2015)
    a. Mainly by local organizers (DWD Lindenberg, DWD Hohenpeißenberg)
    b. Remote access to plots (quicklooks, backscatter profiles, cloud data, housekeeping data) and an option for online discussions for participants
3. Analysis of the obtained data with respect to
    a. Aerosol profiling
    b. Cloud observations

Milestones

M1	circulate proposal among potential participants	January 2015	Done
M2	Circulate questionnaire about already existing datasets of collocated measurements of different ALCs	January 2015	Done
M3	Detailed experiment plan	April 2015	
M4	Perform experiment	June-Aug 2015	
M5	Preliminary report of experiment, including compilation of complete dataset	Sep 2015	
M6	Report on already existing datasets of collocated measurements of different ALCs	Dec 2015	
M7	Final report of experiment results	July 2016	

SWGs and STSMs

Sep/Oct 2015: SWG meeting to discuss results and prepare report/publication

Participants

- Ina Mattis, DWD Hohenpeißenberg
- Ulrich Görsdorf, DWD Lindenberg
- Frank Wagner, DWD Hohenpeißenberg
- Matthias Wiegner, Munich University
- Jan Cermak, Ruhr-Universität Bochum
- Further participants may be added until end of February 2015 (deadline of invitation)