SCIENTIFIC REPORT

ACTION: ES1303 TOPROF

MEETING: ALC WG1, special working group meeting

TITLE: Data format, calibration, and attenuated backscatter profile provision

VENUE: Paris, France

DATE: 10-11 September, 2015

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Introduction

The objective of this meeting was to produce a plan towards provision of calibrated attenuated backscatter profiles from ALC data. Two steps were discussed. The first step concerns the provision of a dataset of calibrated attenuated backscatter profiles based on a few stations and covering a 2-3 months period. The second step concerns providing the E-Profile data hub with all necessary algorithms to start a continuous and operational production of ALC calibrated attenuated backscatter profiles. The time frame for step 1 is October 2015. The time frame for step 2 is spring 2016.

All SWG participants are currently actively involved in developing methods, analyses and code that are necessary for steps 1 and 2.

Results or Achievements

9 different topics were discussed during the SWG. For each, we provide here a summary of our conclusions in a statement, and illustrate this with a figure when appropriate. Further issues and discussions are provided in the appendix.

1. Overall scheme to produce attenuated backscatter profiles; Finalize flow chart

Statement: The group defined that production of ALC calibrated attenuated backscatter profiles will rely on two major codes: (1) RAW2L1 that converts raw ALC measurements provided in manufacturer-defined format into harmonized netCDF files (L1 files); (2) L1-2-L2 that converts L1 data into calibrated attenuated backscatter profiles (L2). L1-2-L2 will include 3 types of data: (i) Attenuated backscatter profiles which are averaged, range and overlap corrected and calibrated; (ii) Attenuated backscatter error profiles; (iii) Flags (saturation, instrument problems). Variables to be included in the L2 files and nomenclature has been discussed. Further discussions are necessary to finalize the flags that will be included in the L2 files.

Each data type will be produced by a specific module:

Module 1 → att. backscatter profiles

- Overlap correction (and potentially the overlap artefact removal)
- Calibration (using calibration coefficients), Unit Harmonization
- Averaging: 5 min, native vertical resolution

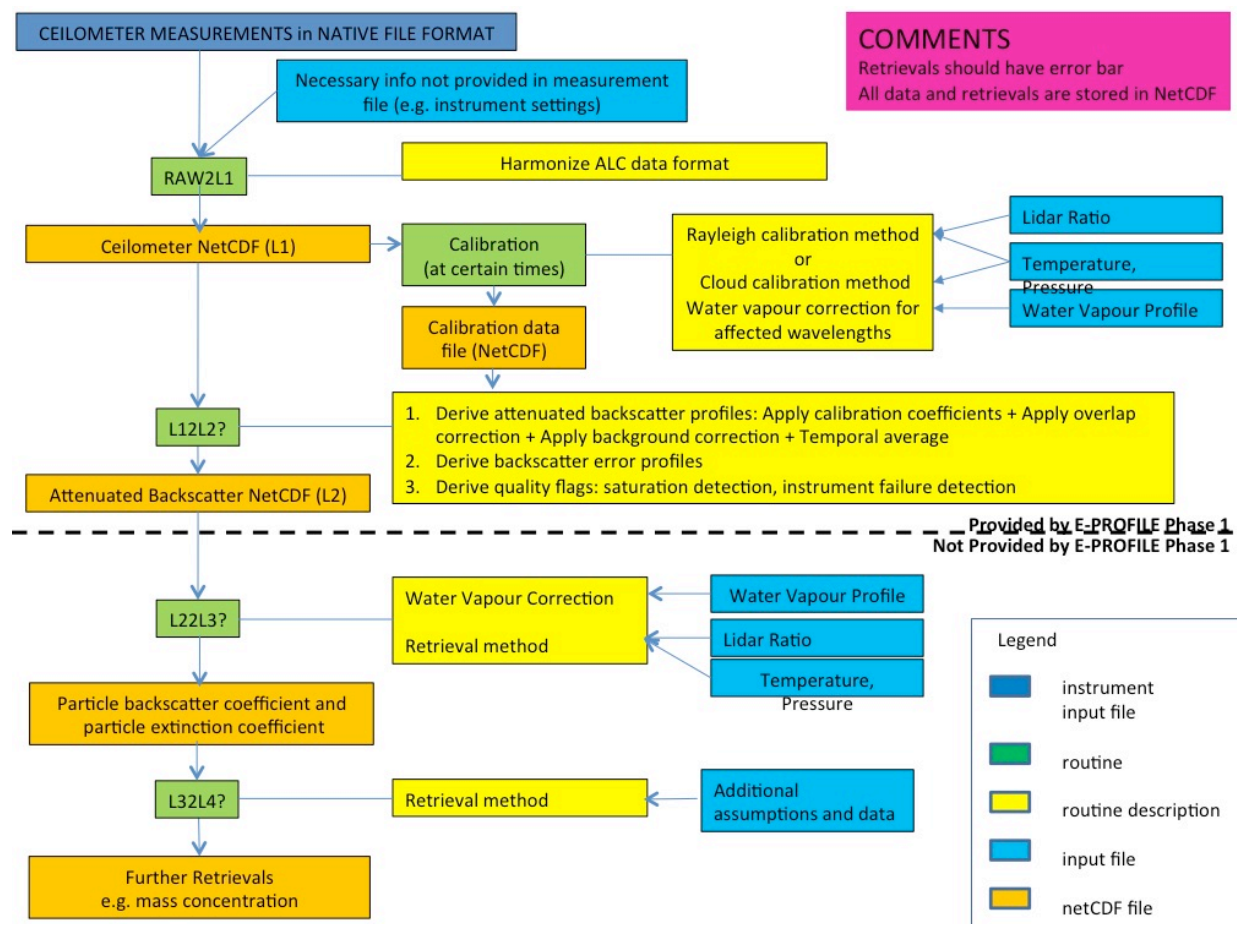
Module 2 → Error profiles from Error calculation routines

Module 3 → Flags

- Saturation detection (in clouds and fog)
- Error detection (laser problem, dirty window, …)

Two additional modules will be necessary:

- A calibration module that provides calibration coefficients to be used as input to Module 1
- A saturation and ringing detection module that identifies such problems in ALC profiles to be used as input to Module 3.



Flowchart presenting input files, routines, routine description, and resulting netCDF files involved in the production of ALC calibrated attenuated backscatter profiles (Level 2; top part of the flowchart)

2. Calibration methods

Statements:

- Rayleigh calibration: consistent results from U. Granada and Meteoswiss
- Cloud calibration: consistent results from UoR and DWD on Camborne site. Further investigations necessary. Manufacturer cloud base heights have a strong influence on calibration results.
- Comparing calibration constants derived by Rayleigh and Cloud method should be done in the future

Issues to be resolved:

- Cloud calibration: quality checks for profile selections should be compared (UoR vs DWD). Emma and Frank/Maxime test the algorithms on Ceilinex data.
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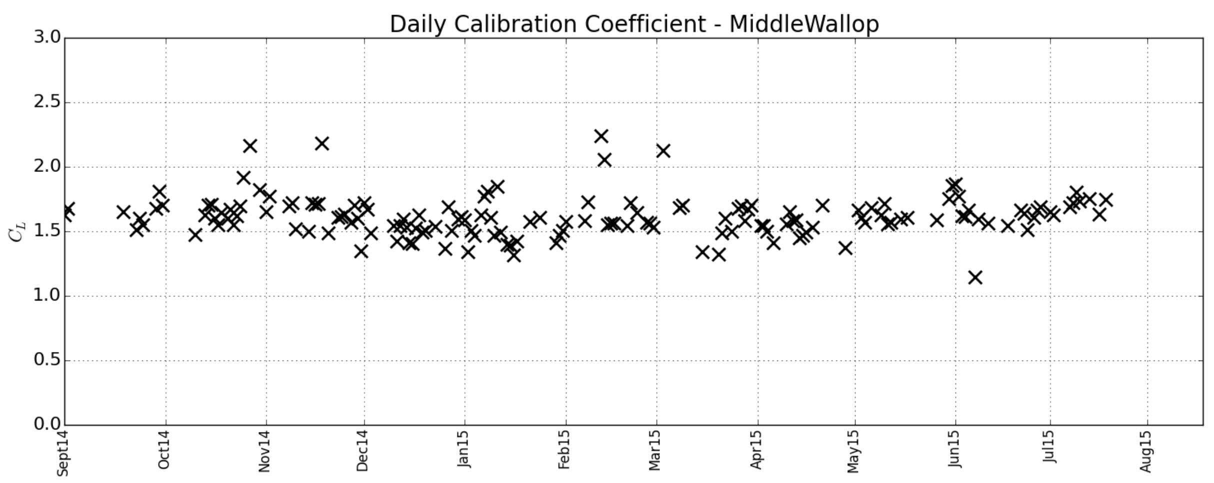
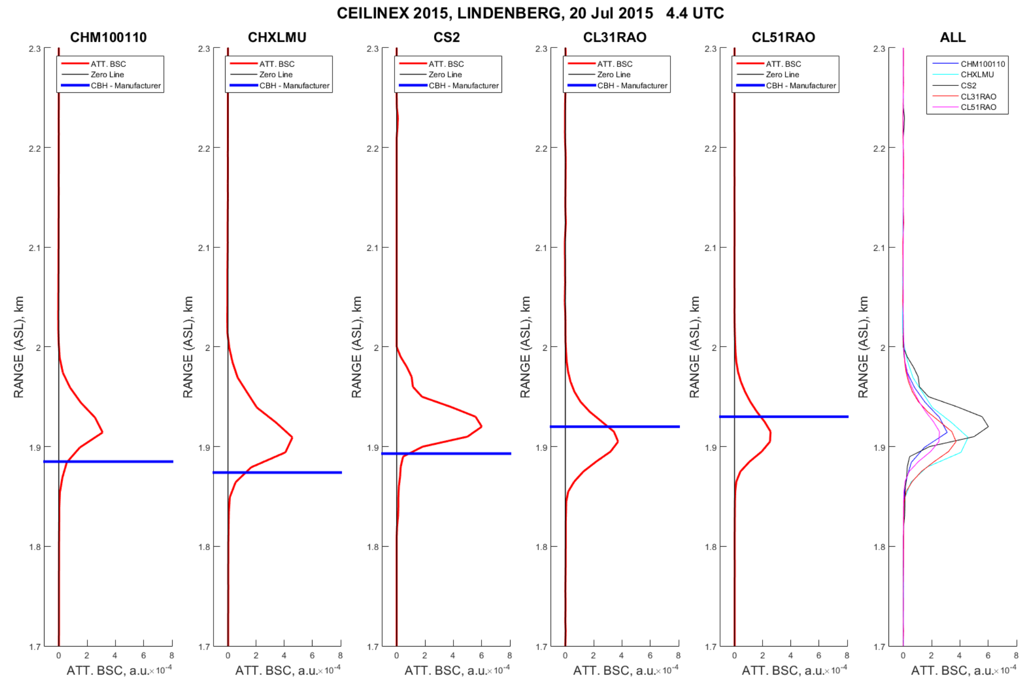


Calibration coefficient for one year (September 2014 – August 2015) at the Met Office site Middle Wallop, England. Calibration = 1.6 +/- 0.15 with no drift or fluctuations over the twelve months. Figure provided by Emma Hopkin (U. Reading).



Cloud base-height (CBH) derived from 5 collocated ALCs during the Ceilinex campaign, showing significant inconsistencies. CBH are obtained by built-in manufacturer retrievals. Figure provided by F. Wagner (DWD). Reminder: there is no definition of CBH

3. Recommendation of CL31/CL51 configuration and firmware

Statement: The firmware version has an impact on the absolute value of the raw signal (attenuated backscatter that is background subtracted, calibrated and overlap corrected by the manufacturer) and a strong impact on noise given the noise zero-level may be slightly offset (Fig. 3.1).First tests of Vaisala Toprof firmware (v2.03) confirm that profiles are not anymore altered for cosmetic reasons and artefacts are removed.

A document is being prepared (Kotthaus et al. 2015) to summarise the critical issues related to different firmware versions and generations of instrument hardware. Further investigation will also use Ceilinex data.

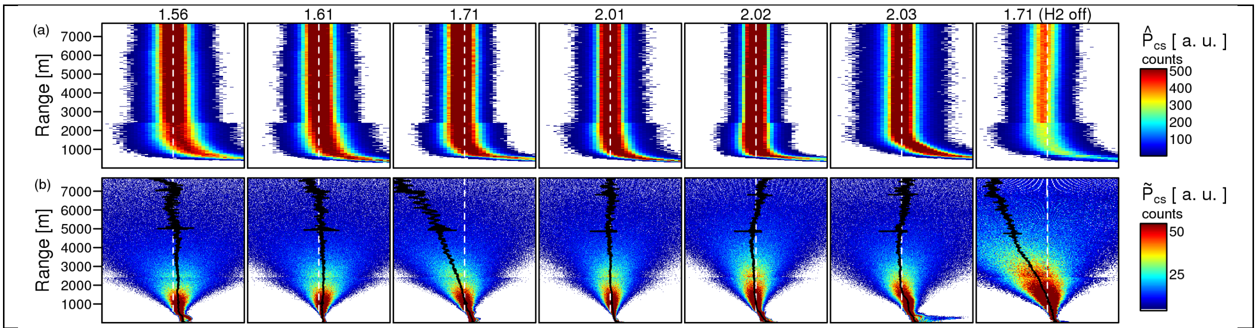
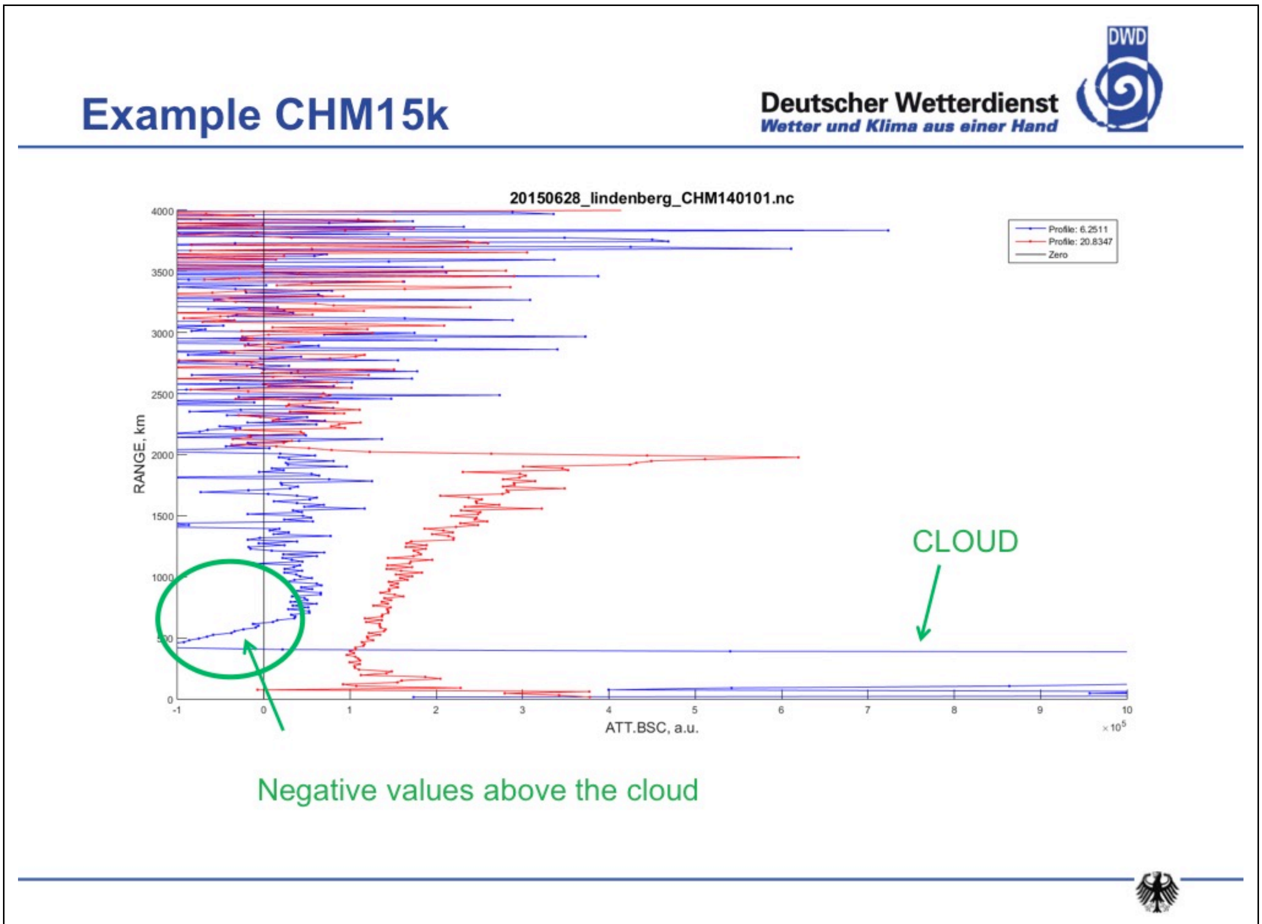


Fig. 3.1: Observations on different clear-sky (no clouds, no significant aerosol layers above PBL) days from CL31 ceilometers (LUMO and Met Office Lidarnet) operating with firmware versions (1.56 – 2.03) and H2 setting = on (resolution: 15 s, 10 m) and firmware version 1.71 with H2 setting = off (resolution: 30 s, 20 m): Range histograms with breaks in arbitrary units (a. u.) of (a) the background corrected signal and (b) the background and range-corrected signal; black solid line denotes median. Each plot contains 24 h of observations. Figure from Kotthaus et al. 2015.

4. CHM15k saturation in deep clouds, CL31/CL51 signal ringing

Statement:

Photon counting detectors might go into saturation when the signal becomes too large and the detector counts several photons as a single event. This can be corrected within certain limits provided that the dead time of the detector is known. For strong saturations the signal gets negative over a range of many bins. This offers a possibility to detect saturation effects within clouds for photon counting devices (see figure). Similar signal shape (negative values directly above the cloud signal) but for different reasons may occur in analogue detectors. Such detectors might start to swing when they receive a very large signal (ringing effect). Hence ringing can also be detected in the same way as saturation.

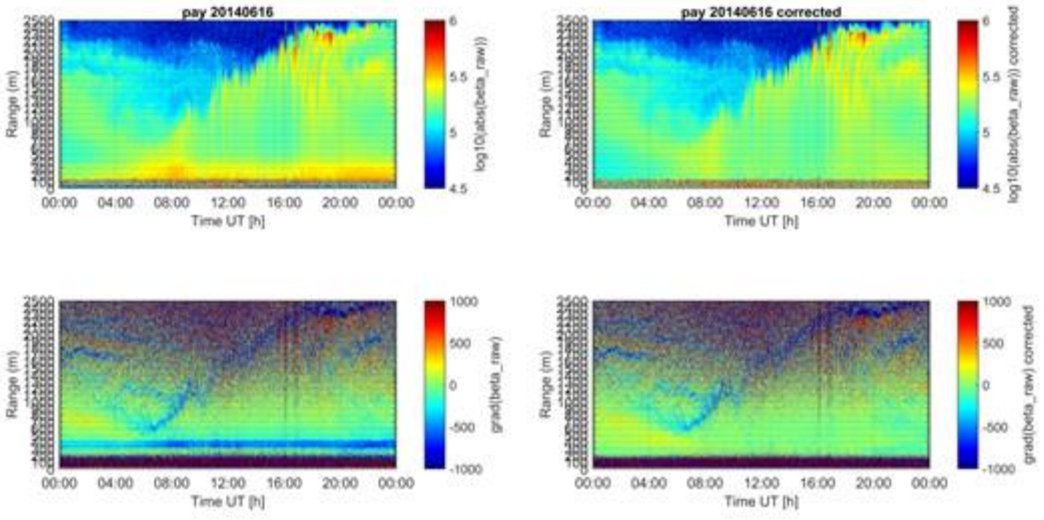


Example of detection of saturation effects within clouds for a photon counting ceilometer. Red curve is an example for cloud free profile on 28 June 2015 measured at Lindenberg. The blue curve is a profile with clouds with the same instrument on the same day. The scale is adapted in order to highlight negative values above the cloud signal. Figure provided by F. Wagner (DWD).

5. CHM15k overlap error

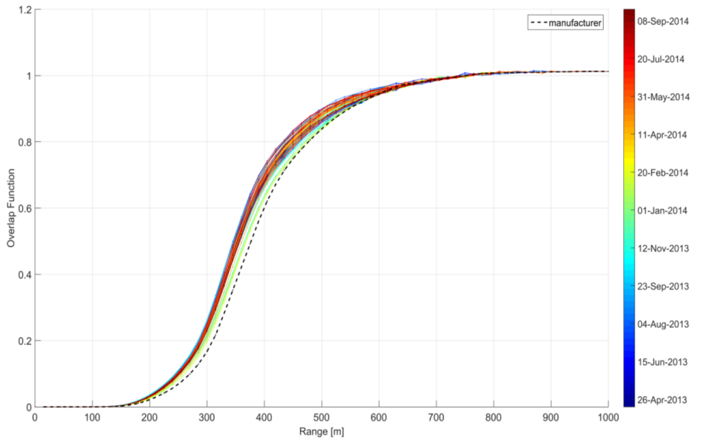
Statement: an artefact at low altitude (100-400m) is apparent on CHM15k data. This artefact is correlated with internal temperature. Yann Poltera proposed a method to correct this artefact based using well-mixed boundary layer conditions. We are expecting input from Lufft on this issue. The manufacturer provides the overlap correction function (errors have to be provided as well). Based on this nominal overlap function, Y. Poltera adjusts this function to real measurements and thus the artefact of the weak band in the first few hundred meters is corrected.

Unfortunately, current analysis of horizontal measurements around Lindenberg showed that the very near range (<300m range) cannot be used for overlap calculations. Only the range further away than 300m might be useful.



CHM15k Measurements at Payerne for the 16/06/2014. Upper panels: Range corrected signals. Lower panels: Gradients of the range corrected signal. Left Panels: without overlap correction. Right panels: with overlap correction.

Figure provided by M. Hervo & Y. Poltera (Meteoswiss).



Daily overlap functions calculated from 01/09/2013 to 01/10/2014 for the CHM15k in Payerne. The Black line represent the reference overlap provided by the manufacturer. Figure provided by *M. Hervo & Y. Poltera* (*Meteoswiss*).

6. Error calculations for attenuated backscatter

Statement: Standard deviation and error propagation based routines exist. They will be implemented by adding the calibration error (for both Vaisala and Jenoptik) and overlap error estimations (for Jenoptik). As agreed during SWG meeting, a 5 min time interval will be used to deliver attenuated backscatter and associated error. For Vaisala, it was proposed to use the standard error of the mean as a measure of the error where the STD is computed over the matrix population covered by the range interval of the last 700m and the time interval of 5 min. Figure 6.1 shows an example of the error computed for Jenoptik for 5 min average, using error propagation (as shown in Roskilde, 2014). For this example, the input error represents only the error associated with the signal following Poisson statistics. A more complete estimation will include also the errors associated with the calibration constant and overlap correction function. E-PROFILE testbed and Ceilinex will be used to provide these errors. For Vaisala, the statistical approach will be estimated for instruments using the new (Toprof) firmware.

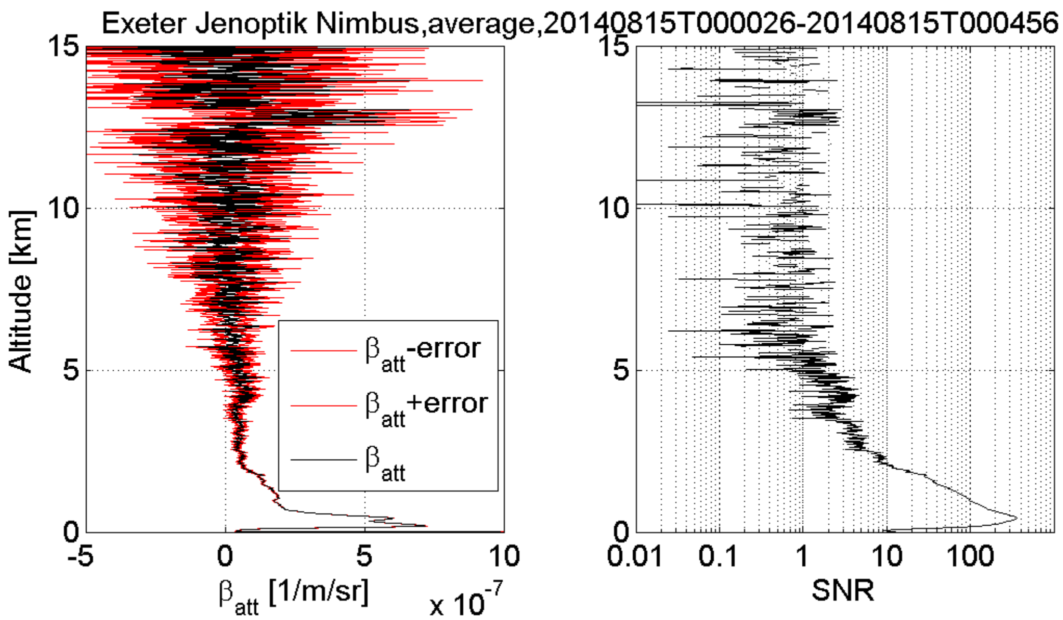


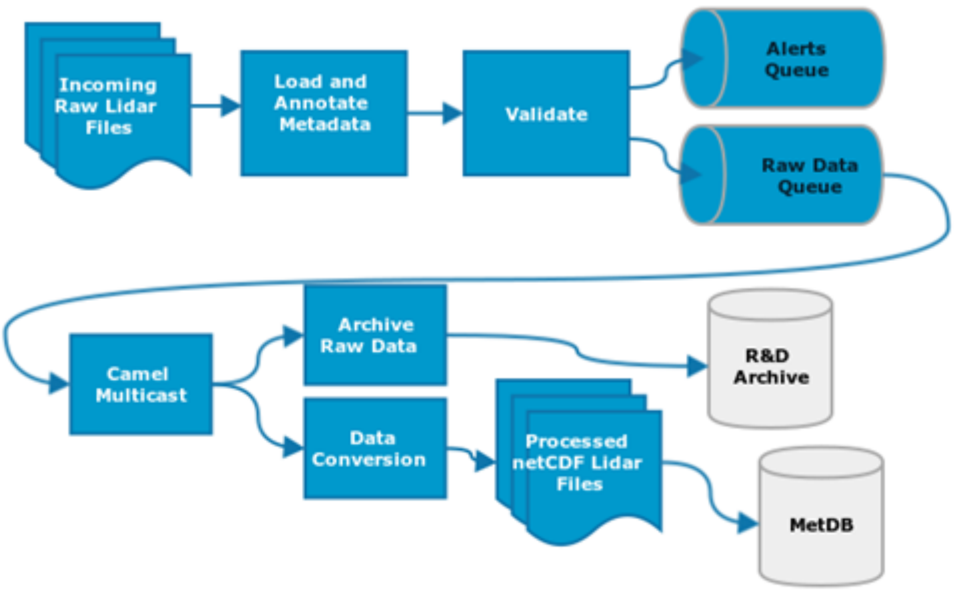
Fig. 6.1. (Left) Attenuated backscatter and associated error over 5 min average using error propagation. (Left) Associated signal to noise ratio for the same time interval. Figure provided by M. Adam (Metoffice)

7. **Implementation to produce attenuated backscatter data (L2) for WG4**

Statement: L2 data files will be produced based on L1 data from the E-PROFILE testbed (10 stations) covering June-August 2015. The goal is to deliver these files to WG4 at the Toprof Toulouse meeting in October.

8. **Implementation at the data hub (Marc-Antoine, Myles, Maxime)**

Statement: At the meeting we discussed how to make theRAW2L1 is compliant with UKMO requirements. During the breakout session we discussed the modifications required to enable the L1 and L2 products to be generated in the E-PROFILE Hub. L1 products are to beimplemented at the E-PROFILE Hub in fall 2015. Next L12L2 modules and calibration module will be implemented (beginning of 2016). The goal is to remain within about 6 month of the initially approved E-PROFILE calendar.



Processing of Ceilometer Data using Hermes.

As part of this architecture we have chosen the following;

a) Python code used for data conversion/scientific processing.
b) Incoming (Raw) data and associated meta-data are stored in a 'postgres' database
c) Processed data are converted to netCDF4
d) We use ActiveMQ as our message broker
e) We use Apache Camel as our scheduler.

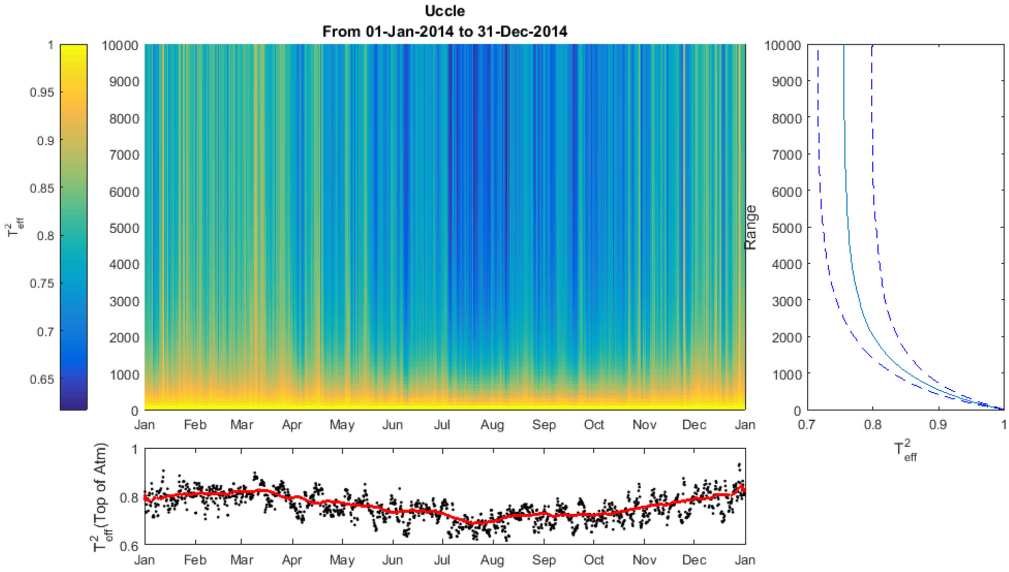
Figure provided by M. Turp (Metoffice)

Incoming data will be processed as follows;

a) Incoming raw data are converted to L1 (Data conversion step in above diagram)
b) Additional data feeds containing model fields will need to be ingested to accommodate the L1-L2 Conversion (this will run as a scheduled task once a day to update the calibration data information for each instrument)
c) The L1 files will be used to create the L2 using the calibrated data information generated in b) and by implementation of additional calibration/correction modules as described in this report.
d) The L1 and L2 products will be stored the UK Met Office (MetDB) database.
e) Quicklook plots will be generated and made available for E-PROFILE monitoring.
f) Products/Data will be distributed (subject to permission from the data provider)

9. Water vapor correction implementation and evaluation

Statement: Water vapour absorption at 910 nm (905-915) can generate 20-30% errors in extinction coefficient retrievals (error depends on water vapour mixing ratio and laser temperature/wavelength). See Wiegner, M., & Gasteiger, J. (2015).



Temporal variability of water vapor absorption effect on two-way transmission between ground and ALC profile altitude. Clear annual cycle at the top of the atmosphere. Average Correction factor ~30% at 5000m. Figure provided by M. Hervo (Meteoswiss), based on a TOPROF STSM in collaboration with M. Wiegner (LMU).

Conclusions and summary

The objective of this SWG was to produce a plan towards provision of calibrated attenuated backscatter profiles from ALC data. The SWG permitted significant progress to be reached concerning ALC processing.

Implementation of RAW2L1 processing at E-PROFILE data hub was discussed in details. A plan to provide attenuated backscatter profiles which are averaged, range and overlap corrected and calibrated, was established. Most important issues were addressed. The group would like to note that manufacturers are supporting the TOPROF investigations, which is very helpful.

The Ceilinex campaign organized and hosted by DWD will be an extremely important dataset for further investigations of calibration, overlap, and firmware version issues.

The scientific report will be posted on the TOPROF website: www.toprof.eu.

References

Kotthaus, S., E. O'Connor, Ch. Münkel, C. Charlton-Perez, and CSB Grimmond, 2015: Processing Profile Observations from Vaisala CL31 Ceilometers, in preparation.

Wiegner, M., & Gasteiger, J. (2015). Correction of water vapor absorption for aerosol remote sensing with ceilometers. AMTD. http://atmos-meas-tech-discuss.net/8/6395/2015/amtd-8-6395-2015.pdf

CEILINEX: http://www.ceilinex2015.de/

Appendix listing unresolved issues and topics to be further discussed

Topic 1

Suggestions for flags

- Good reliable data
- No information, i.e. when SNR is too small, when we have cloud and the beam is fully attenuated…above such clouds we have no info
- Maybe we flag also reliable cloud backscatter data (I guess: below maximum cloud bsc in water clouds, maybe ac is ok, cirrus clouds are difficult. The bsc might have a deattenuation effect) and unreliable cloud backscatter data which (I guess: above maximum cloud in water clouds)
- flag for Vaisala's AN signal distortion (negative belly). Similar with saturation or ringing. We also can advise on dark measurements to eliminate this effect.

Overlap:

- Overlap correction is performed just applying Lufft's overlap correction function while the overlap artifact removal is a separate routine to be applied (developed by Poltera)
- The routine works well for strong artefacts. The problem is that vertically homogenous conditions are required. It is unclear how they are defined. It is impossible to distinguish small overlap errors from small vertical inhomogeneities

Module 1:

- It is suggested that unit harmonization be done in L1-2-L2, as RAW2L1 does not convert RAW data into other units. To be discussed
- Do we want to restrict profiles to a maximum height? Or is the maximum altitude dependent on SNR and varies with instrument and atmospheric conditions?

Module 2:

- Error calculations could be included in module 1 since errors is computed along with attenuated backscatter as you go. When computing errors, one needs more input than the mean attenuated backscatter profile computed in module 1. Even we define here two modules, I hope that at the end we have only one routine for both.

Calibration module:

- Frank Wagner suggests 2 different calibration modules:
CM1: Calibration at certain times when the weather permits calibration
CM2: Interpolation of results of CM1 for old data with respect to 5min temporal resolution and Extrapolation with respect to new data

Topic 5

Please recall what Lufft said about overlap: "And to explain a bit more our correction function, it is important to know that the function in TUB...cfg is not a pure overlap correction but a correction which is calculated by comparing each measure unit with our reference unit. The overlap function of the reference unit was determined on a day with a homogenous boundary layer. The correction function is determined in a way that the corrected signals of both measuring units are equal".

Topic 6

Suggestion: Is it planned to calculate the error for Lufft ceilometers in the same way as for Vaisala ceilometers? Only then we could compare Vaisala and Lufft errors. If this is not planned, I suggest using different vocabulary for highlighting the different error/uncertainty calculations.