SCIENTIFIC REPORT

ACTION: ES1303 TOPROF
MEETING: ALC WG1, special working group meeting
TITLE: CeiLinEx2015 data analysis
VENUE: Munich, Germany
DATE: 8-9 October, 2015

Produced by: Ina Mattis (DWD, Germany)
Submission date: 10.11.2015

Contribution by: Neda Boyouk (DWD, Germany), Juan Antonio Bravo-Aranda (SIRTA, France), Mike Brettl (Campbell Scientific, UK), Jan Cermak (RUB, Germany), Ulrich Görsdorf (DWD, Germany), Martial Haeffelin (SIRTA, France), Maxime Hervo (MeteoSwiss, Switzerland), Kateřina Komínková (Czech Globe, Czech Republic), Ronny Leinweber (DWD, Germany), Christoph Münkel (Vaisala, Germany), Margit Pattantyús-Ábrahám (DWD, Germany), Christophe Pietras (SIRTA, France), Gregor Pittke (DWD, Germany), Yann Poltera (MeteoSwiss, Switzerland), Kornelia Pönitz (Lufft, Germany), Frank Wagner (DWD, Germany), Matthias Wiegner (LMU Munich, Germany)

Introduction

The objective of this meeting was to coordinate the analysis of the data that have been obtained during the CeiLinEx2015 campaign. CeiLinEx2015 was an ALC performance intercomparison campaign that took place at Lindenberg, Germany from June to September 2015. All SWG participants were/are actively involved in the organization of the experiment and in the analyses of the derived data set.

Results or Achievements

Ten different topics were discussed during the SWG. For each of them, we provide here a summary and illustrate it with a figure if appropriate.

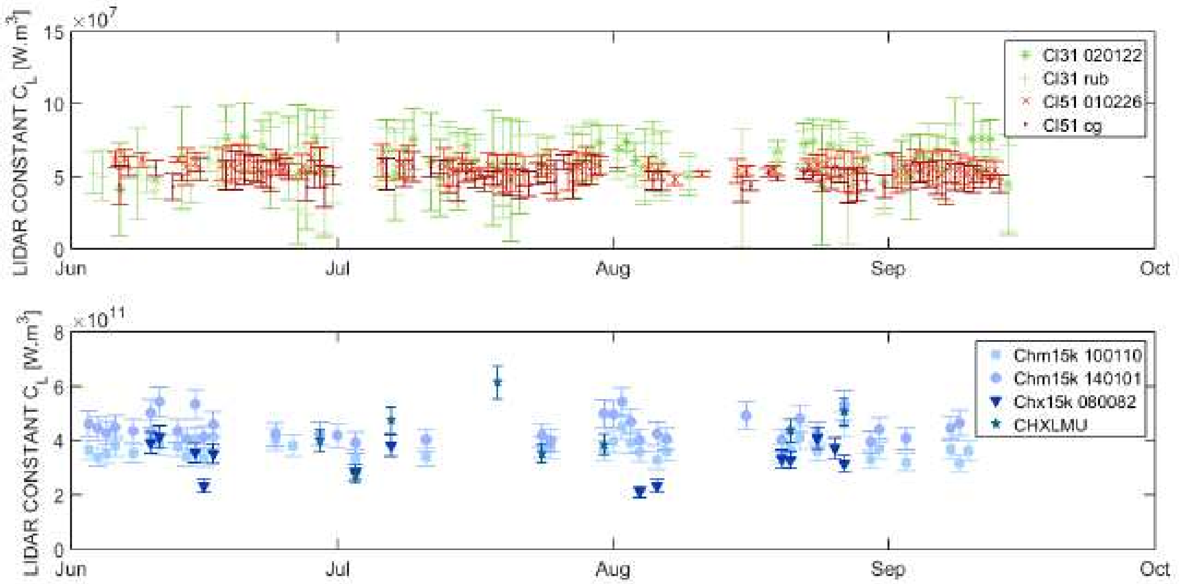
1. Overview on available data

A general overview on the data which were collected during the campaign was provided.

- Campaign period was from 1 June to 15 September 2015 (complete data set between 25 June and 31 August)
- Participating ceilometers (2 of each type) were LD40, CL31, CL51, CHM, CHX, CS135 plus Aerosol lidar RALPH as reference system.
- For CL31, CL51, and CS135 different firmware versions and parameter settings were tested.
- At the instrument webpage (ceilinex2015.de) you find
    - General overview on practical issues (coordinates etc)
    - Logbook with instrument changes and events (e.g. firmware changes, window cleaning, special measurements)
    - Discussion of first results (with option for comments)
    - Overview on all measurement days (synoptic situation, quicklooks of signals and housekeeping data)
- Special measurements have been performed
    - Dark current
    - Telecover
    - Horizontal
- Several Saharan dust events during the campaign period:
    - 12-14 June
    - 3-7 July
    - 15-18 July (strong)
    - 6-16 August (strong)
    - 30 August – 1 September
- Aircraft observations during the campaign:
    - 25 June: DWD volcanic ash equipment (2 aircrafts)
    - 30 August: new extinction instrument (Forschungszentrum Jülich, AWI)
- Data collection at FTP server
    - Still needs homogenization (e.g. labelling of special measurements)
    - Still needs completion of ancillary data

2. Calibration

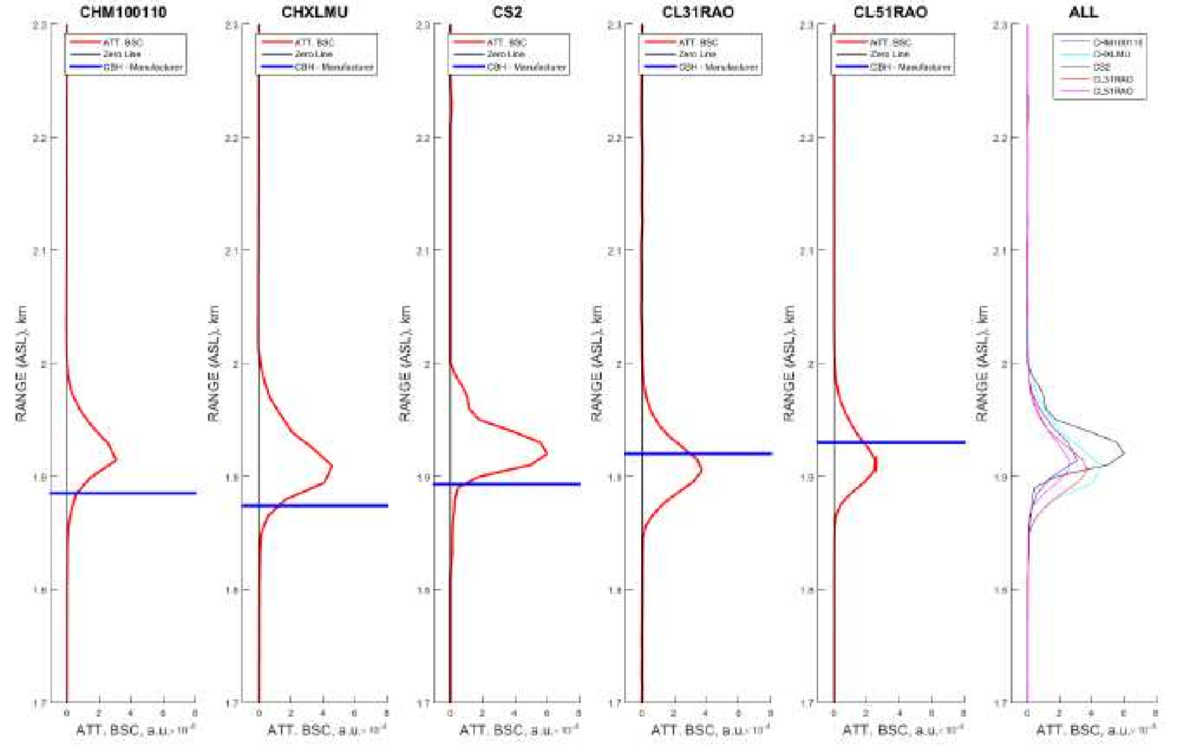
The calibration of the ceilometer data obtained during CeiLinEx2015 is one of the basic steps that have to be carried out before most other analysis procedures can be applied. Due to different measurement techniques, different calibration methods are appropriate. Rayleigh calibration (RC) was applied to the instruments of CHM and CHX type. Calibration at the base of water clouds (CC) was applied to the instruments of CL31 and CL51 type. For this purpose, a new algorithm was developed which allows for the detection of the base of well-defined water clouds from the raw data of all ceilometer types. The calibration of the data from CS135 instruments has not yet been performed. The CC should be appropriate, but the program code still needs some minor adaptations concerning data format. A third calibration method, which is suitable for all instrument types, is the calibration with a reference instrument. Calculation of calibration factors with this method can be an independent tool for the quality control of RC and CC. Data of the reference instrument (Raman lidar RALPH) are available for almost the complete experiment period.



Time series of calibration factors obtained with CC method (top) for CL31 and CL51 instruments and with RC method (bottom) for CHM and CHX instruments. Figure provided by M. Hervo (MeteoSwiss).

3. Cloud base height

One major goal of CeiLinEx2015 is to characterize differences in the ability of the individual instruments to detect clouds and to measure cloud base heights. Most important for aviation purposes is the reliable detection of low clouds and the accurate determination of their base heights. There is a systematic bias in the cloud base heights reported by the different systems which is caused by system specific technical characteristics (e.g., overlap function) and algorithms for cloud base estimations. It was discussed in the SWG, that the different manufacturers use different definitions of cloud base height in their algorithms as it is illustrated in the figure below. For very low clouds, in rain, during fog dissipation and for ice clouds, cloud base estimation is much more complicated and may result in even larger differences in cloud base height and in in different detection rates. In order to allow for more meaningful comparisons between the output data of the different instruments, it will be necessary to apply one and the same algorithm to the raw data of all instruments. This could potentially be the new algorithm for cloud base detection developed by DWD for the CC calibration method. Further, it is necessary to agree on a common quantitative, physical definition of cloud base height.



Raw data profiles (red) of a low water cloud measured by different instruments at the same time and location. Blue lines indicate the cloud base heights as detected by the manufacturer algorithms. Figure provided by F. Wagner (DWD).

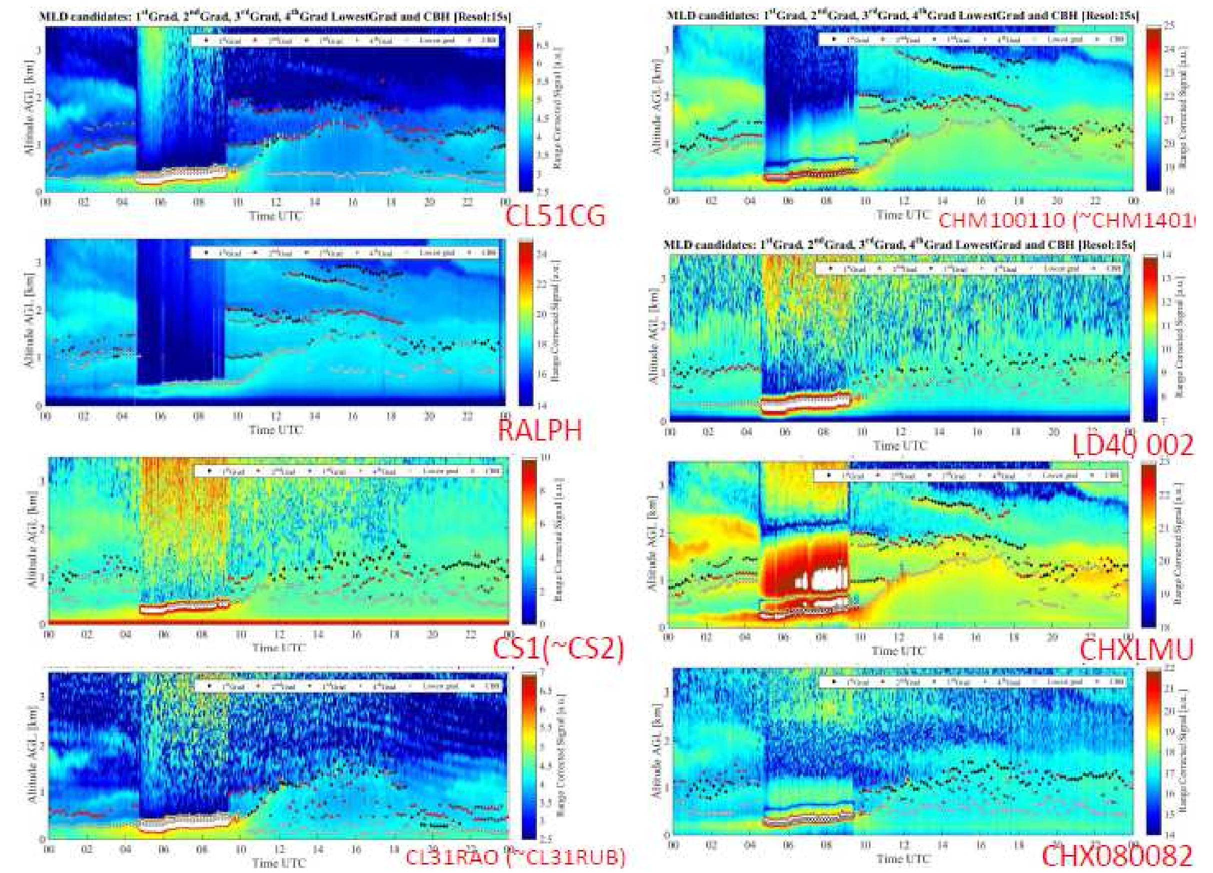
4. Correction of water vapor absorption

The raw signal profiles of all ceilometers with laser wavelengths between 900 and 920 nm are affected by absorption due to water vapor molecules in the atmosphere. Those are instruments of the types LD40, CL31, CL51, and CS135. If calibration factors or backscatter profiles are retrieved from those data without correction of the water vapor absorption, the results may be affected by an error up to 20% [Wiegner et al. 2015]. The quantification of this effect and/or its correction requires the knowledge of the exact laser wavelength and of the actual water vapor density profile. The former are not available from all manufacturers

The data of CeiLinEx2015 allow for a verification of the method proposed by [Wiegner et al. 2015]. High-quality vertical profiles of water vapor concentration are provided by 4 radio-sonde launches per day. The raw signal profiles at 1064 nm measured by the CHM instruments and by RALPH are not affected by the water vapor absorption and can be used as reference measurements.

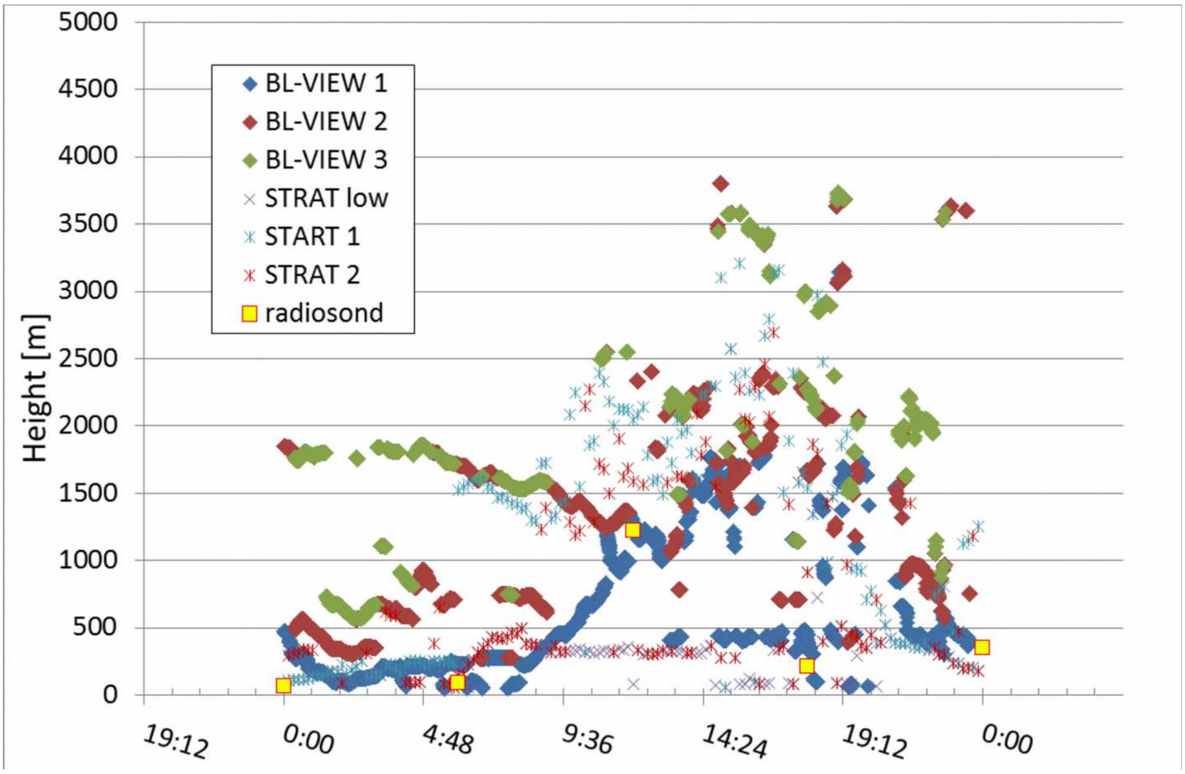
5. Determination of PBL heights

A fully automated algorithm for PBL height detection (STRAT+) was applied to the raw signal profiles of all participating instruments. STRAT+ determines several possible candidates for the PBL top height and finally, it decides which of these candidates is the most probable one. Additionally, PBL top heights can be determined from radio sonde launches 4 times per day with an independent method [Beyrich and Leps, 2012]. The comparison of the PBL heights retrieved with STRAT+ from different instruments with the PBL heights from radio soundings allows for an optimization of instrument specific STRAT+ input parameters.



Time-height plots of raw data measured by different instruments on the same day and at the same location. Dots indicate different candidates for PBL height retrieved by STRAT+. Figure provided by J.A. Bravo-Aranda (SIRTA, France).

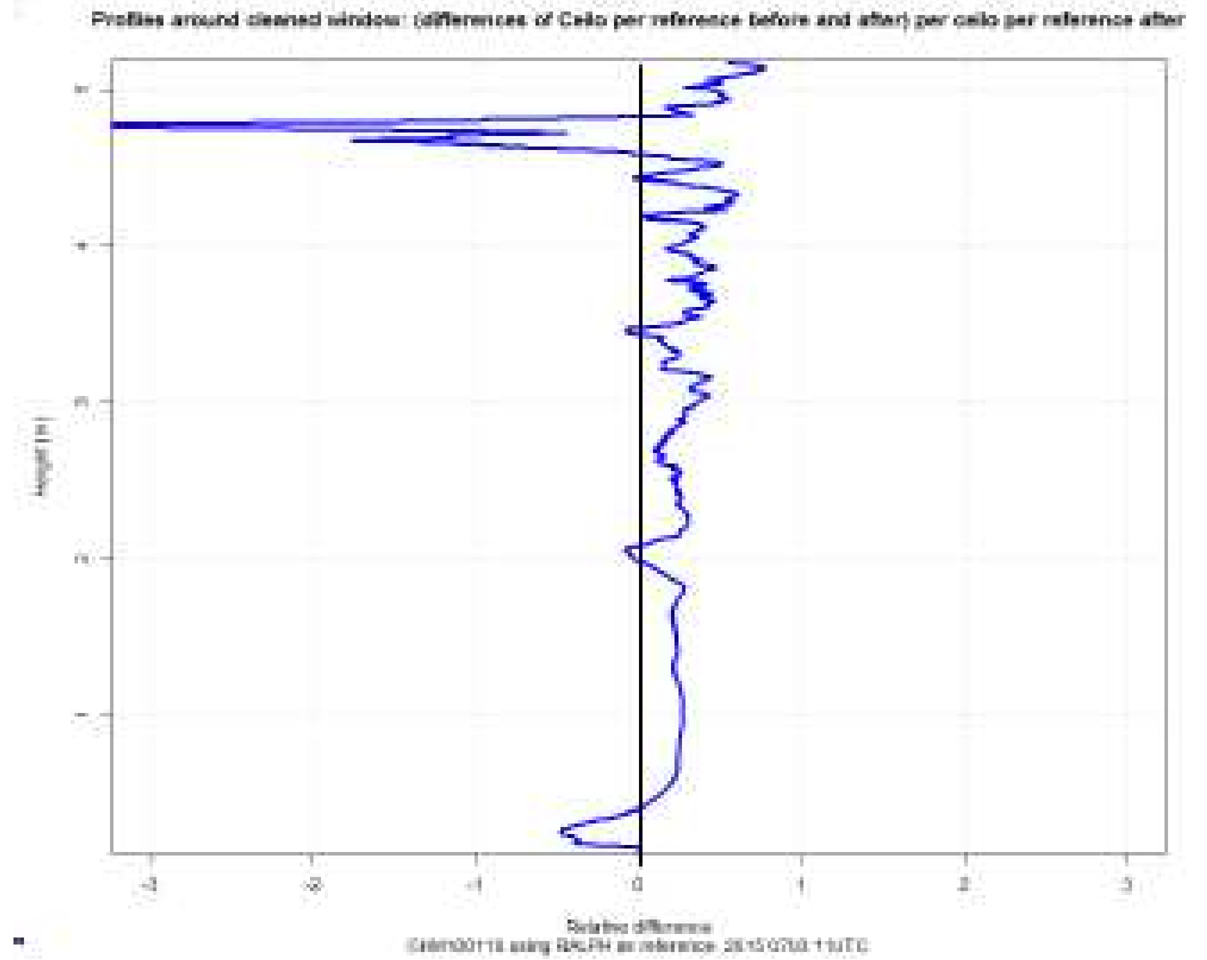
Another approach is the comparison between PBL heights retrieved by different algorithms from data of the same instrument. As an example, those comparisons between STRAT and BLView (software by Vaisala) were peformed for the data of the CL51 instrument of Czech Globe.



Different candidates for PBL height retrieved by STRAT and BLView from the raw data of CL51CG of 13 June 2015. Figure provided by Kateřina Komínková (Czech Globe).

6. Correction of window transmission

The transmission of ceilometer windows is influenced by long-term processes like deposition of dust or by fast processes like window cleaning or leaves falling on the window. This property affects the accuracy and validity of calibration factors and thus, it causes uncertainties in the retrieved backscatter profiles. All analyzed instruments provide a housekeeping parameter 'window transmission' in their data files. A case study demonstrates that this parameter can be used to correct ceilometer data under favorable conditions (slowly increasing, homogeneous, semi-transparent pollution of the window). In case of non-transparent objects that suddenly cover the window only partially (e.g., leaves), this correction does not work. Therefore, it is essential to monitor the temporal evolution of the window transmission parameter.



Relative change of signal intensity between two time periods, before and after cleaning of the window. Figure provided by Margit Pattantyús-Ábrahám (DWD, Germany).

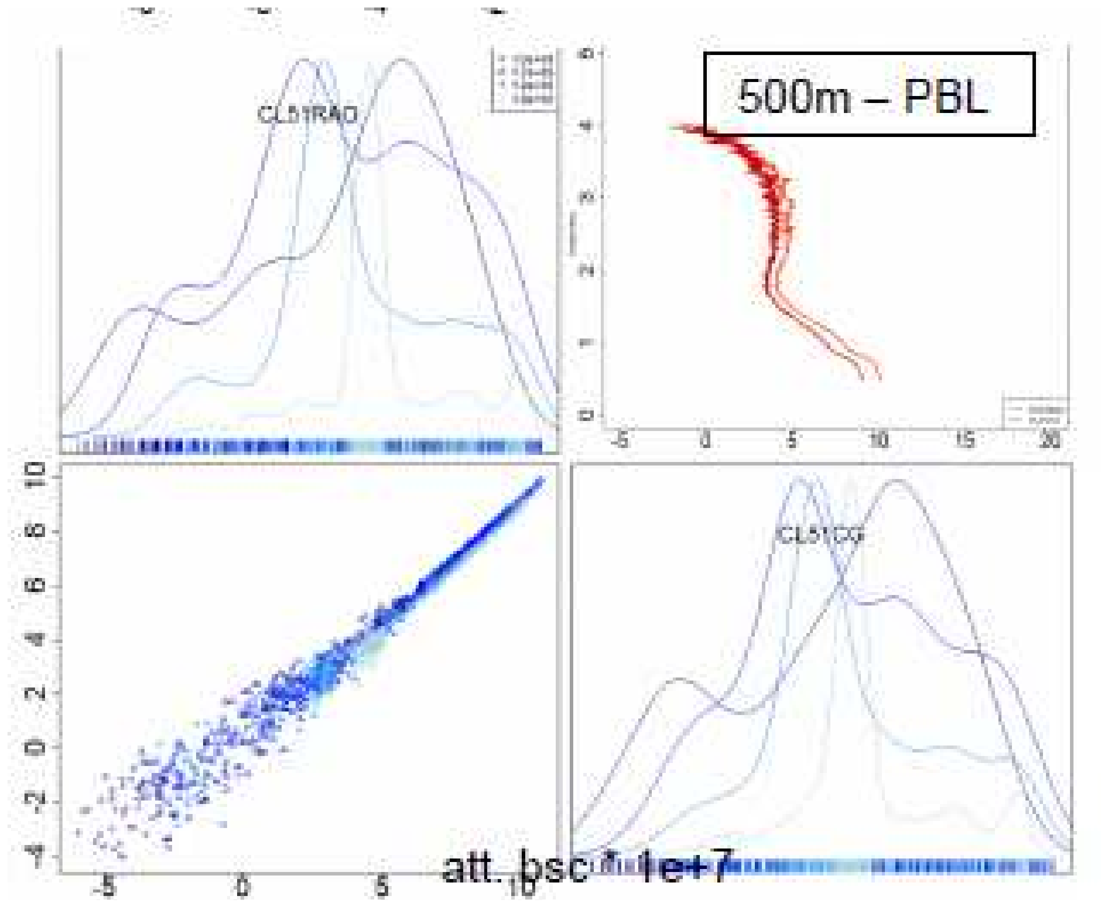
COST is supported by
the EU Framework Programme
Horizon 2020

7. Instrument-to-instrument variability

One major goal of CeiLinEx2015 is the investigation of significant differences between profiles of attenuated backscatter coefficients (calibrated) from different instrument settings. Those differences shall be studied with a statistical approach for three altitude regions

- below 500m (potentially influenced by overlap)
- between 500m and top of PBL (no overlap effect, good signal-to-noise ratio),
- between top of PBL and 5km (potentially influenced by background effects, small signal-to-noise ratio)

for different meteorological conditions, different instruments, and firmware versions. Different case studies were presented to illustrate the proposed method.

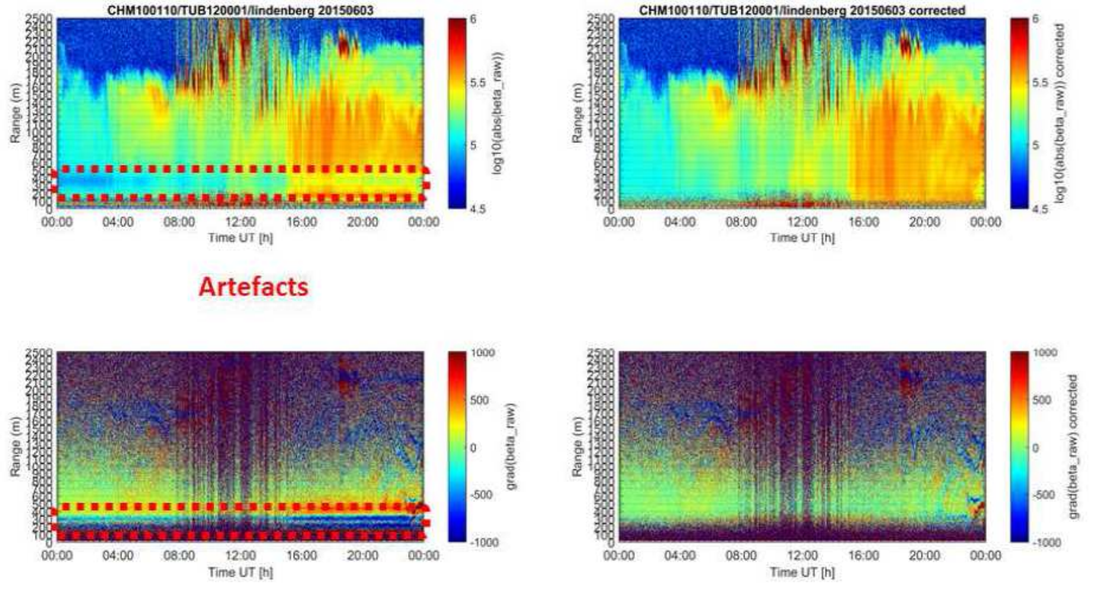


Comparison of the two CL51 instruments at 11 August 2015 between 16 and 20UT. The different colors indicate different hourly mean values, darkening with increasing time. CL51RAO was operated with TOPROF firmware, CL51CG with usual firmware. The panels in the diagonal show probability distributions. Lower left panel provides the correlation plot and upper right panel the corresponding profile plots. Figure provided by Margit Pattantyús-Ábrahám (DWD, Germany).

8. Instrument effects in the overlap region

In general, all lidar or ceilometer instruments are affected by the incomplete overlap between the emitted laser beam and the field of view of the receiver telescope (short term for this effect: ‘overlap’) at low altitude ranges. If the shape of the so-called ‘overlap function’ is known, the measured signals can be corrected. This correction is implemented in the firmware of all manufacturers. Any correction with an incorrect overlap function may cause systematic deformations of the corrected signal. Those deformations are very small compared to the signal errors without overlap correction. Usually, they do not affect the accuracy of retrieved cloud base heights or backscatter profiles. In contrast, uncertainties of the applied overlap correction have a significant influence in case of applications where the vertical gradient of the lidar signal is retrieved (e.g. detection of PBL top heights). For these applications, it is necessary to detect and – if possible – further correct for remaining systematic signal deformations due to not-perfect overlap correction. Systematic signal deformations can be detected with two methods which have both been applied during CeiLinEx2015.

- *Vertical measurements in well-mixed PBL conditions* (assumption of vertical homogeneity of the atmosphere). This method was applied to the data of the CHM instruments, but not yet to the data of the CL31, CL51, or CS135 ceilometers.



Example (CHM100110, 3 June 2015) of the improvement of the overlap correction. Panels on the left show the uncorrected, panels on the right the corrected data. The top-row panels show time series of attenuated backscatter, the bottom-row panels show the vertical gradients as they are used for the retrieval of PBL top heights. Figure provided by Maxime Hervo and Yann Poltera (MeteoSwiss, Switzerland).

- *Horizontal measurements* (assumption of horizontal homogeneity of the atmosphere). These measurements were performed with all participating ceilometers from different places in different directions. A first analysis of the data indicates that the assumption of horizontal homogeneity of the atmosphere is not valid around the observatory and overlap correction functions cannot be derived from individual horizontal measurements. Nevertheless, a more complicated approach using simultaneous horizontal and vertical measurements of instrument pairs may give better results.

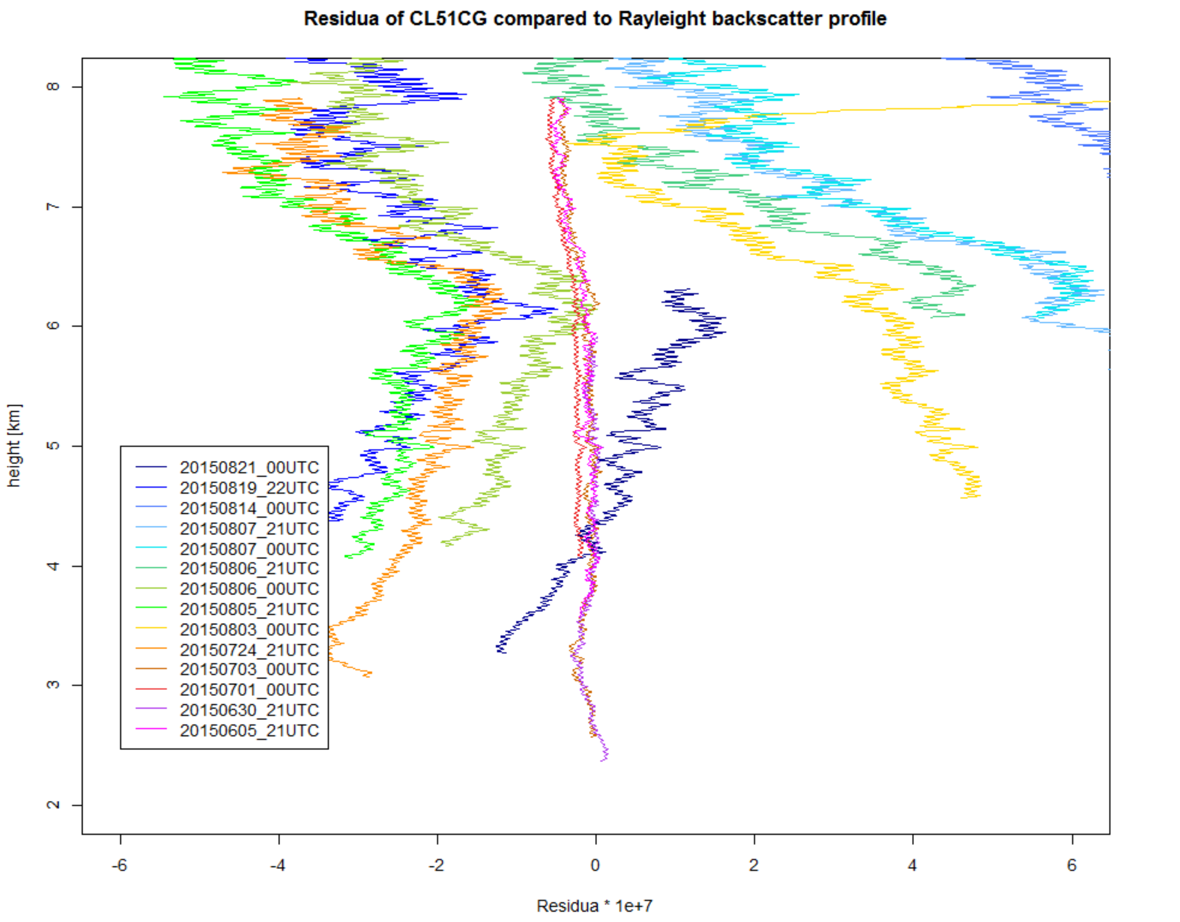
Simultaneous horizontal measurement with a CHM and a CL31 instrument. Foto by Ulrich Görsdorf (DWD, Germany).

9. Signal distortions in the free troposphere

Usually, ceilometer types with analog signal detection units (CL31, CL51, and CS135) show systematic distortions of the measured raw signals in the free-troposphere altitude region. Those distortions may indicate non-existing aerosol layers. Furthermore, they significantly decrease the quality of Rayleigh calibration. During CeiLinEx2015, two methods were tested to quantify the shape and intensity of the distortions. If the distortion profiles can be determined with sufficiently low uncertainty, corresponding raw signals can be correct for the effect. The two methods are:

- *Calculation of the Rayleigh residual profiles*. If it is known from measurements with a reference instrument (e.g., RALPH) that backscatter profile in a certain altitude range is caused by molecules only (Rayleigh scattering), the Rayleigh residual is the difference between the measured signal and the actual Rayleigh backscatter signal which can be estimated from radiosonde data. These residual profiles represent the systematic distortion profiles

- *Measurement of dark current profiles*. For these measurements, the receiving telescope is completely covered, but the instrument is operated as usual, including emission of a laser beam. The measured dark current profile corresponds to the electronic background signal.



Example: Rayleigh residual profiles of the CL51CG instrument, measured at different days. Figure provided by Margit Pattantyús-Ábrahám (DWD, Germany).

It seems that both methods often result in profiles with markedly similar shapes. Thus, dark-current measurements could be used to correct measured raw signals. Rayleigh residual profiles can be used as a measure for the validation of this correction method (not yet done).

Conclusions

The objective of this SWG was to provide an overview on the available data to all CeiLinEx participants, to organize next steps of data analysis (including establishment of new cooperations), and to find an agreement concerning next steps of publication of experiment results and of data.

The campaign will provide a very valuable dataset to many other tasks of WG1 in TOPROF.

The group would like to emphasize that manufacturers supported the campaign, especially the exchange of expertise was very useful.

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

References

Beyrich, F. & Leps, J.-P. (2012). An operational mixing height data set from routine radiosoundings at Lindenberg: Methodology. Meteorologische Zeitschrift

Wiegner, M. & Gasteiger, J. (2015). Correction of water vapor absorption for aerosol remote sensing with ceilometers. AMTD.