SCIENTIFIC REPORT

ACTION: ES1303 TOPROF
MEETING: ALC WG1, special working group meeting
TITLE: CeiLinEx2015 data analysis
VENUE: Vienna, Austria
DATE: 19-20 April, 2016

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Submission date: 25.05.2016

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Introduction

The objective of this meeting was to discuss the progress of the data analysis of the CeiLinEx2015 campaign since the last SWG in October 2015 in Munich. CeiLinEx2015 was an ALC performance inter-comparison 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

10 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. Data availabality and status of data homogenization and screening (Margit Pattantyús-Ábrahám)

Margit Pattantyús-Ábrahám reported on the current status of the data format standardization. The data transformation from original Vaisala and Campbell message formats are done by Ronny Leinweber by using Raw2L1. The first outputs of the Raw2L1 resulted in a quite diverse data format. Therefore the usage of the resulted netcdf data is cumbersome: Quasi each ceilometer type requires an own read-in program. It is expected to publish the data, and at the time of the publication the data files should be as ceilometer-type independent as possible.

Main problems with the data:

- Same quantities have different variable names (e.g. tilt angle appears as azimuth, zenith_angle, tilt_angle).
- Same quantity for the same ceilometer: variable name switched back and forth during the experiment (for Campbell instruments cloud base height: cb or cbh).
- Coordinate information are given for some ceilometers as global attribute for others as variable.
- Some variables are not present but can be obtained, and added for all the ceilometers (e.g. wavelength, range_resolution).
- Attributes do not contain firmware-version and firmware-options (like overlap algorithm) metadata.

The data are standardized and have been uploaded to the FTP server (). Until now, the main focus was mainly on the standardization of the variables in the netcdf files, and on the addition of the proper firmware-related metadata, which was completely missing from the files. Frank Wagner recognized that the global attributes are not uniform, and for some ceilometers they vary in time. This should be amended before the data publication.

Data of the reference lidar RALPH have been converted into a ceilometer-like NetCDF format containing raw signals and range- and background corrected signals. Hourly mean values of backscatter coefficient at 1064 nm and of calibrated attenuated backscatter are available, too. But those were not yet uploaded to the FTP server. This will be done very soon.

Holger Wille mentioned that some of the variables provided by different manufacturers may describe similar quantities (e.g. window_transmission or state_optics), but they are merely indicators and the variable values should not be compared directly.

2. **New, extended data policy (Ina Mattis)**

All participants agreed on the new, extended data policy (which is valid until the data will be finally published)**:**

a) Measured profile and cloud data are provided by DWD together with ancillary data to all participants via password protected FTP server. The credentials shall not be distributed to third parties.

b) When TOPROF or EPROFILE members are interested in working with our data, they shall be given access to the data upon a short email describing the planned studies.

   i) All relevant results shall be communicated to the CeiLinEx team. For any sort of publication including presentations, co-authorship must be offered to all CeiLinEx members.

   ii) If one of the CeiLinEx groups is already working on the same topic – both groups shall try to negotiate about combining their efforts for mutual benefits.

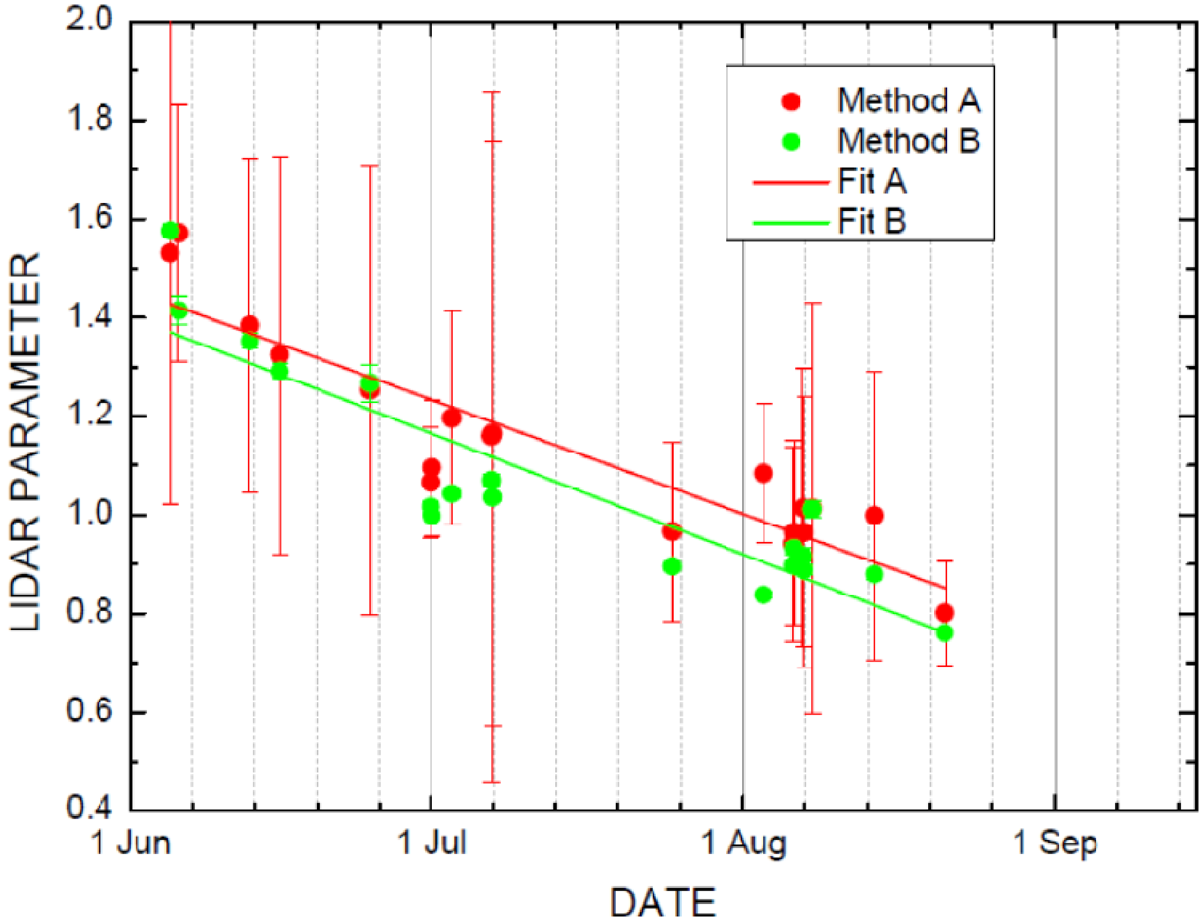
c) Finally, all results shall be published (at least CeiLinEx participants shall be informed about all results). All participants agree to publish their data with respect to the purpose of this campaign.

d) All participants remain the owner of the data delivered by their instrument. If data of the campaign shall be used and published for other studies, the data owners have to be asked for agreement and co-authorship shall be offered.

3. Status of Calibration (Maxime Hervo, Frank Wagner, Ina Mattis)

There are no new calibration values for the ceilometers. Lidar parameter data of all instruments (mean, median, and standard deviation) will be compiled into one txt file and uploaded to the FTP-Server.

The Lidar parameter of RALPH changed with time due to a decreasing laser power. Two different methods have been applied to derive the lidar parameter of RALPH. The corresponding linear function will be also put into the txt file.



Method A: Lc = 1.46 E8 – 8.65 * t

Method B: Lc = 1.40 E8 – 9.15 * t

t in seconds since 2016-06-01 00:00:00

$\beta_{attn}(z) = rcs(z) * Lc$

Figure 1 Temporal decrease of lidar parameter of RALPH

4. Is correction of window transmission possible (Margit Pattantyús-Ábrahám)

Margit Pattantyús-Ábrahám reported on analysis on the effects of the variation of window transmission conditions. Effects of dust accumulation, window cleaning, partial coverage were analysed. The window transmission slightly affects the measurements, but it is hard to quantify this effect from the provided value, other metadata are necessary for correct interpretation. Window_transmission /state_opics variables are not directly comparable for Vaisala / Lufft instruments. Smaller window transmission /state_optics values during measurement (except rain) may indicate higher uncertainty in the measurements.

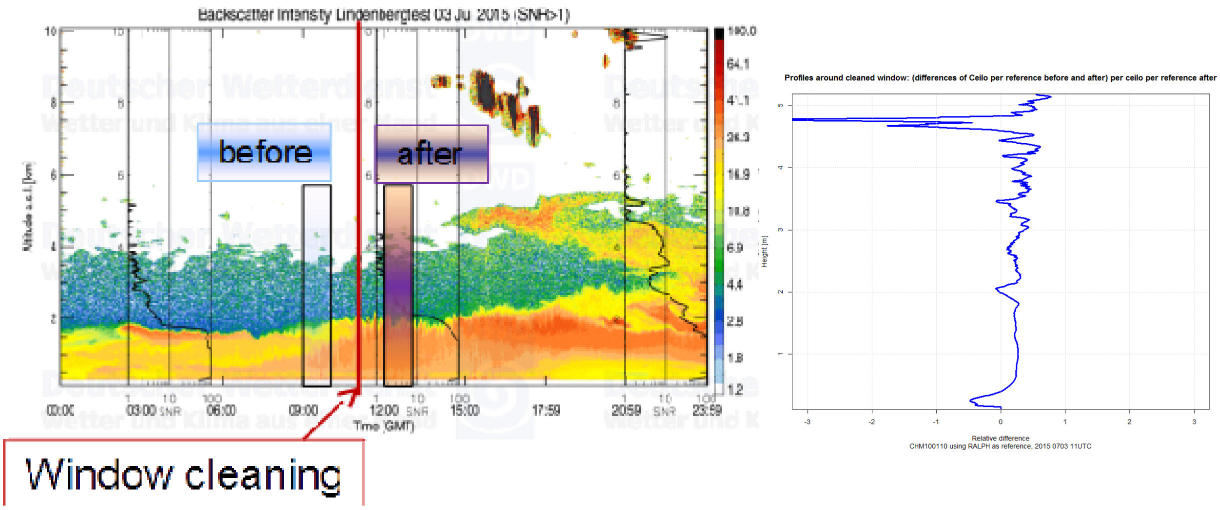


Figure 2. Example for the effect of window cleaning CHM100110 at July 3, 2015

5. Determination of near-range (overlap) correction functions (Yann Poltera, Maxime Hervo)

CHM15k ceilometers may have an overlap function which is not properly determined by the manufacturer in the first few hundred meters, creating artefacts in the vertical gradient field (which is problematic e.g. for the mixing layer height detection and makes the inter-comparison between ceilometers difficult in this near-range region).

The incorrect overlap functions can be corrected with an algorithm, and this has been shown for specific dates on specific sites (Payerne,20140616 ; SIRTA, 20150408 ; Kleine Scheidegg, 20150704 ; Granada, 20130308 ; LindenbergCHM140101, 20150602). All the cases show an improvement over the overlap function given by the manufacturer, making overlap artefacts in the vertical gradient field disappear. The method used is described in the manuscript currently under review (Hervo et al., 2016). The main result of this work, namely the temperature dependence of the overlap correction, has been shown with figures for the CHM15k ceilometer of Payerne. Similarly concluding results have been obtained for the CHM15k at the Kleine Scheidegg (mentioned but not shown during the meeting).

The algorithm has been applied on the CEILINEX campaign data of the CHM15k ceilometers CHM140101 and CHM100110. All obtained corrected overlap functions have been used to construct a temperature-dependent correction model for both ceilometers. The temperature-dependent correction found for the CHM140101 gives satisfying results, but not the one for the CHM100110. This is maybe due to insufficient representative data for this ceilometer (indeed, we recommend constructing the correction model from at least one year of data), or the assumption of a temperature dependence is not entirely correct for all CHM15k ceilometers (Matthias Wiegner reported that Alexander Geiß found in the framework of his PhD-thesis an overlap-dependence on the sensor's input voltage (CHM15k-X ceilometer). Holger Wille (from the CHM15k manufacturer Lufft) predicts a dependence on the difference between the external an internal temperatures (which creates a stress on the window)).

6. Status of validation of correction of water vapor absorption (Matthias Wiegner)

Matthias Wiegner reported on the current status of the water vapor correction of CL51 ceilometers.

The theoretical background is described in Wiegner and Gasteiger (2015). It includes the establishment of a data base with mean water vapor absorption cross section profiles and the calculation of water vapor mixing ratios profiles from radio sonde ascents at Lindenberg. Both steps were successfully performed. For the emission spectrum of the laser diode realistic assumptions were made; a refinement is not necessary at the time being. From this information the effective water vapor transmission – necessary for the correction of the measured signals – could be calculated.

Data sets of simultaneous measurements of two CL51-ceilometers and two Lufft-ceilometers could be accessed from the ftp server that was set up by the DWD. CL31-data are also available, but their evaluation has a lower priority and was thus postponed.

The inversion of particle backscatter coefficients currently suffers from the missing calibration of the ceilometers, uncertainties of the overlap correction and signal distortions in the Rayleigh regime. With this respect the Vienna SWG-meeting was very useful as these problems could be discussed and possible next steps towards a solution were proposed. Moreover, an agreement on dates which should be evaluated with highest priority could be found.

7. **Signal distortions in the free troposphere (Frank Wagner, Josh Vande Hey)**

Knowing instrument artefacts is quite important for a comprehensive understanding of measurements and subsequent analysis. The nature of some artefacts is such that they can be corrected. Other artefacts cannot be corrected and they will either lead to an increased measurement error or will make impossible certain analysis. The list of known artefacts is increasing every TOPROF meeting.

Here is an incomplete list of currently known artefacts and their potential treatment in the data analysis

1) Detector saturation

Description: The signal measured by a detector might become saturated for low clouds. All instruments by all 3 manufacturers suffer from this effect. Due to different principle of detection, the devices by Vaisala and Campbell show this effect much less frequent that Lufft devices. Identification of the effect: significant undershooting above a cloud over a range of several bins. Solution: Flag these profiles as not-usable for aerosol profiling. Note: the cloud base height can still be determined.

2) Near field back reflex CS135

The detector receives a strong signal in the lower 100m. This signal is caused by backreflection of a small portion of the emitted laser light. It prevents the use of this part of the profile for aerosol analysis. But cloud height measurement is still possible even for altitude below 100m. Solution: the profile can be modified by replacing the lower 100m with the backscatter value of the profile directly above. Note that this

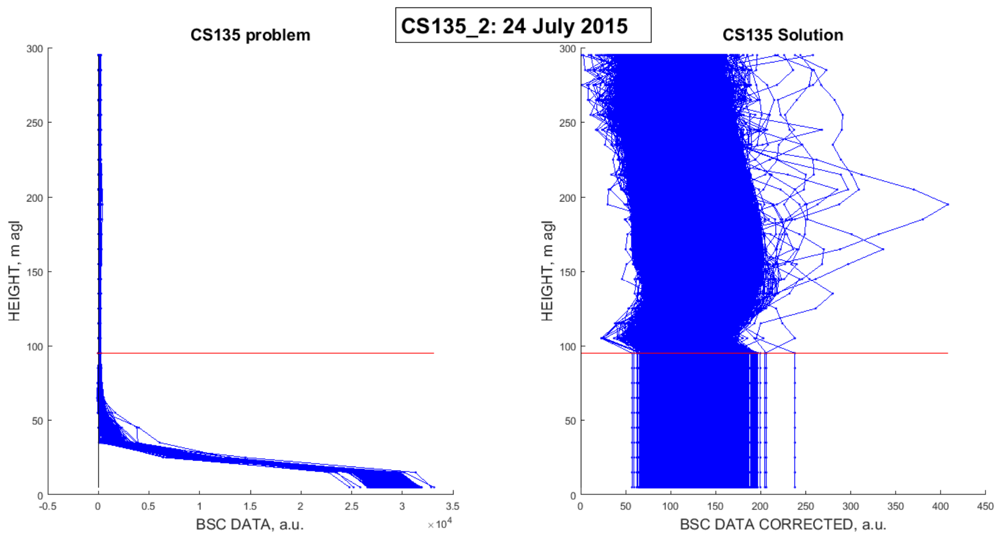


Figure 3. Illustration of the near-range reflection of CS135 instruments.

correction is for aerosol attenuated backscatter. For low cloud detection and vertical visibility calculation the built-in CS135 digital signal processing extracts clouds and vertical visibility from the close range multiple scattering signal, so this correction is only needed for the aerosol attenuated backscatter for which the signal to noise ratio is not sufficient for extracting aerosol information below 100m.

3) Belly in the free troposphere

Vaisala instruments show a small belly in the free troposphere. This belly does not allow to perform a Rayleigh calibration with the instrument. Furthermore it suggests the existence of a weak free trophere aerosol layer when in reality the free troposphere is almost aerosol free. Currently it is assumed that this belly can be corrected. It is unclear how well this correction would work.

4) Instrument Noise:

Terminology and procedures for subtracting instrument noise were discussed. First, there was agreement that dark current was not the correct term for the noise that is subtracted if the instrument receiver is covered. Josh Vande Hey proposed that perhaps the term “instrument noise” was more appropriate given that the noise signatures in ceilometers often contain a mix of optical and electronic noise and ringing due to close proximity of detector to laser and amplifier electronics to laser electronics, as well as the potential for inadvertent multiple scattering of photons within the optics.

In the CS135, the impulse response of the receiver is characterized and corrected for in order to correct for artefacts resulting from the AC-coupled configuration of the electronics and the frequency and phase response of the amplification stages. However this impulse response based correction cannot compensate for inadvertent optical leakage within the optomechanical system, or electronic noise due to the electrical disturbance caused by firing the laser. For this reason, an instrument noise subtraction routine can be carried out by fully covering the receiver optics of the system. For the CeiLinEx campaign, averaged background measurements of this instrument noise were carried out for one instrument in the laboratory and can be subtracted from any campaign data for which the full Campbell data message was used, although there is likely to be a higher degree of uncertainty than there would have been if the same procedure had been carried out in the field for both instruments.

8. Effects of depolarizing scatterers on signal intensities (Margit Pattantyús-Ábrahám)

Margit Pattantyús-Ábrahám reported on the study of depolarized scatterers. Depolarising scatterers are e.g. volcanic ash, ice clouds and Saharan dust. The study focused on the Lufft CHM instruments: one of them was vertically pointed and the other was tilted by 5°, same as RALPH. The proportion of the attenuated backscatter profiles to RALPH was investigated. The proportion to RALPH of the vertically pointed ceilometer backscatter was ~25% more than the tilted's . The dependence of the proportion to RALPH on cloud height, optical depth, RMSE, correlation, cloud type, profile load, etc. were studied. It showed slight dependence on cloud height and optical depth, and higher dependence on cloud type/Saharan dust. During the discussion, it was mentioned that the effect might have an arbitrary component. Further measurements of this effect with the same instrumental setup, but different instrument individuals are currently carried out at Hohenpeißenberg.

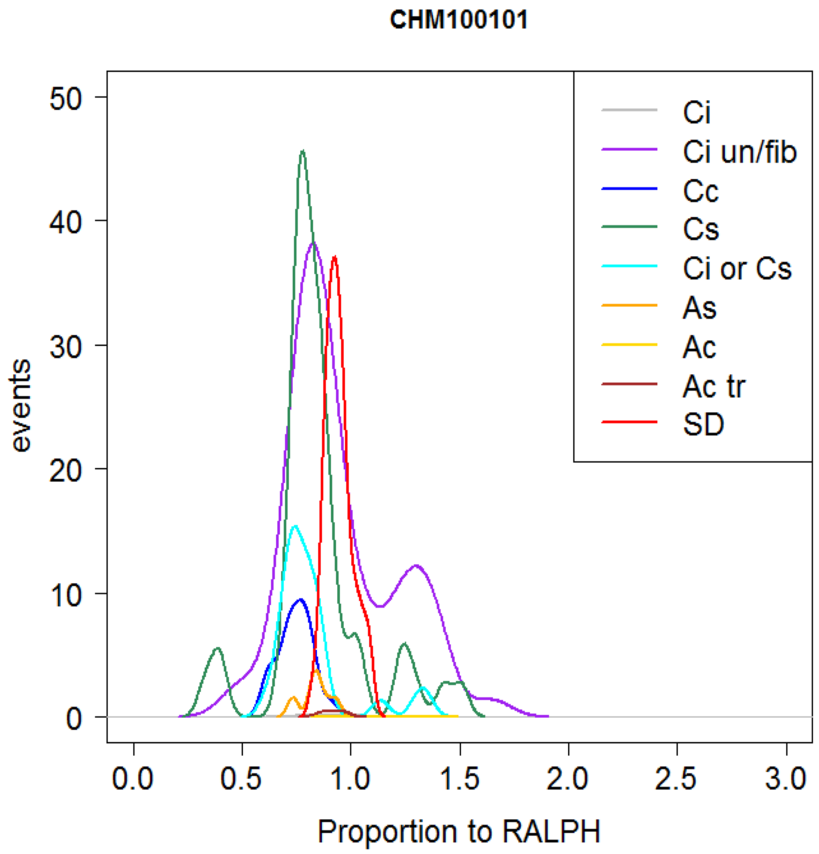


Figure 4. Proportion of the CHM100110 signals (tilted by 5°) to RALPH for different types of cirrus clouds and Sahara dust

9. Cloud base heights (Ulrich Görsdorf)

The analysis of ceilometers to detect clouds and to derive cloud base heights has been continued. Similar cloud types and weather situation are summarized in order to get a representative statistics for cloud base height differences, detection rate and repeatability. Maximum cloud base height differences between the systems of about 70 m are observed for stratocumulus and 40 m for low stratus. With one exception the cloud detection rates agree well within about 3% and 6 %, respectively.

Cloud base height differences can be explained by different algorithms and criterions applied by the manufactures to derive the cloud base from backscatter profiles and a nonexistent quantitative definition of cloud base height. Therefore, an experiment is planned by DWD for 2016/2017 in Hamburg to compare cloud base heights from different ceilometers (CL31, LD40, CHM15k) with camera images of a 300 m high tower in order to get information about the visibility based cloud base height which is most relevant for aviation control. The impact of the viewing angles on results has been discussed.

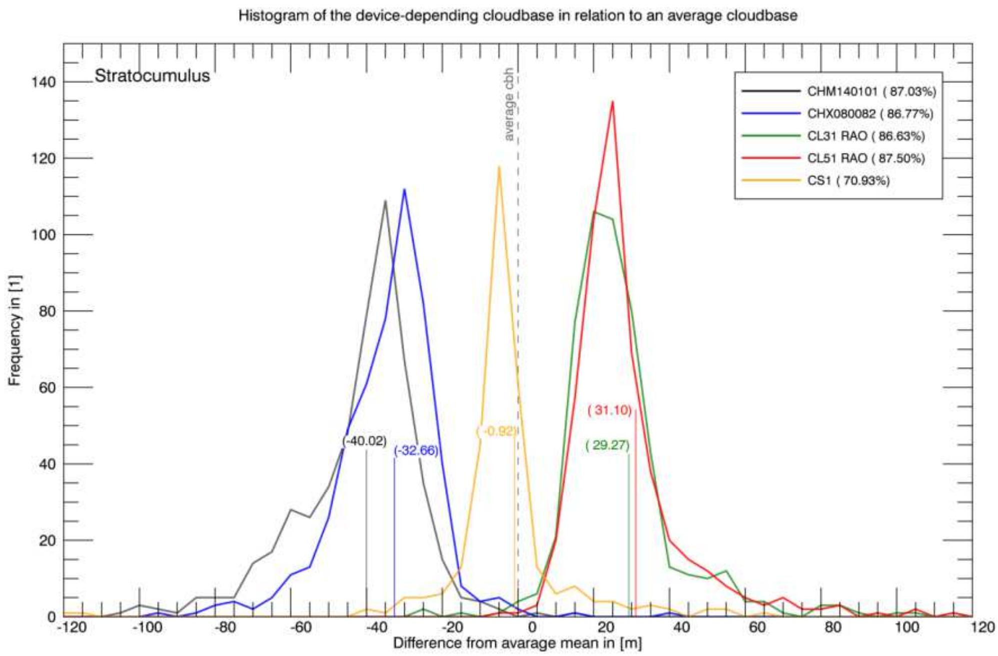


Figure 5 Frequency distribution of cloud base height differences regarding a common mean value considering 19 cases of Stratocumulus (about 10 hours in total)

10. Instrument-to-instrument variability (Margit Pattantyús-Ábrahám)

Margit Pattantyús-Ábrahám reported on the first results of the instrumental variability analyses.

Therefore events with clear sky conditions were manually selected and the boundary layer top heights were determined for each day. During the investigation hourly means of backscatter data were used. The hourly profiles were split into 3 vertical regions: From the ground to 500m a.s.l.; from 500m a.s.l. to the PBL top; From PBL top to 6km a.s.l. .

The following metrics were used to compare the profiles of ceilometers with each other and to RALPH's and their time series were shown for each vertical region, respectively:

- Pearson correlation
- Spearman (rank) correlation
- Linear regression coefficient: $y \approx a*x$, where x and y denote backscatter profiles of different ceilometers, and parameter a is the regression.
- It was suggested during the meeting, that RMSE should be also used for the analyses.

The aerosol load of the vertical profile was also taken into account.

The investigation was at preliminary phase at the time of the SWG Meeting, detailed PBL top height data from SIRTA and calibration values for the backscatter profiles were not available before.

Conclusions

The objective of this SWG was to present the current status of the CeiLinEx data analysis, to discuss preliminary results, and to organize next steps of data analysis.

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

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

Hervo, M., Poltera, Y., and Haefele, A.: An empirical method to correct for temperature dependent variations in the overlap function of CHM15k ceilometers, Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2016-30, in review, 2016