

An empirical method to correct for temperature dependent variations in the overlap function of CHM15k ceilometers

Answers to Referee 1

By M. Hervo et al.

The authors would like to thank the reviewer for his constructive remarks. For each comment, the answers are given below.

The revised manuscript with all the changes highlighted is provided separately.

Anonymous Referee #1

Received and published: 7 April 2016

General comments:

The paper describes an overlap correction method for ceilometers that bases on the simple assumption of a homogenous boundary layer combined with a known a-priori overlap function. A sophisticated quality check is described that identifies the homogenous layers and is shown in an appropriate example. A temperature dependence of the overlap correction was found and a linear model could be applied to account for this dependence. Thus, an ensemble of overlap correction functions can be generated and used for a range of occurring temperature variations inside the instrument. The implementation of this methods for automatic retrieval makes it particularly useful for networks of similar instruments, such as the recently implement ceilometer networks.

The paper is written clearly and concise. Some English grammar may be corrected for.

I recommend the paper for acceptance with minor corrections.

Specific comments and technical corrections sorted by page and line:

- p. 2 and p. 3. L, 19-23: Please explain the Sasano et al. (1979) method briefly to the reader.

The following sentence was added: "To identify cases with a homogeneous atmosphere, Sasano et al. (1979) proposed to use the ratio between the received power from two altitudes and to require that it is stable over time."

- p. 3, l. 26: "(previously Jenoptik)" can be misunderstood - by readers not so familiar with the history of the CMH15k ceilometers: Not the Company Lufft was former called Jenoptic, but Jenoptic is another company that has manufactured the ceilometer before. Please clarify.

"previously Jenoptik" was replaced by "previously manufactured by Jenoptik".

- p. 4, l 26-28 and p. 5, Eq. (2): $O(r,t)$ and $o(r,t)$ may be confusing.

The correction function $o(r,t)$ was replaced by $fc(r,t)$ in all the manuscript.

- p. 5, l. all equations: Very small letters! Difficult to read.

We acknowledge that the equations might be difficult to read, but we used the AMTD template.

- p. 5, l. Eq. (3): Did you also take the number of laser pulses, lp , into account?

From the definition in the netcdf files:

β_{raw} : long_name = 'normalized range corrected signal

$(\text{signal_raw} / lp - b) / (c * o(r) * p_cal) * r * r'$

P is now explicitly defined as received power **per pulse**.

- p. 5, l. 14: Please define the lidar ratio as extinction-to-backscatter ratio.

The following sentence was added: “also defined in the literature as extinction-to-backscatter ratio”.

- p. 5, l. 16 and for Eq. (6) and (7): Please define molecular and particle backscatter coefficients as β_m and β_p and the respective extinction coefficients as α_m and α_p .

β_p , α_p , β_m and α_m are now defined on page 5.

- p. 6, l. 2: sr not Sr.

Corrected.

- p. 6, l. 4 -5: An illustration of the “straight-line-approximation” of term A1 and the right hand side of Eq. 7 could improve the immediate/intuitive understanding of this fact.

The following figure represents an illustration of Eq. 7 for different aerosol extinction coefficients and Lidar ratios. This figure clearly shows that the right hand side of equation 7 can be approximated as a straight line at 1064nm.

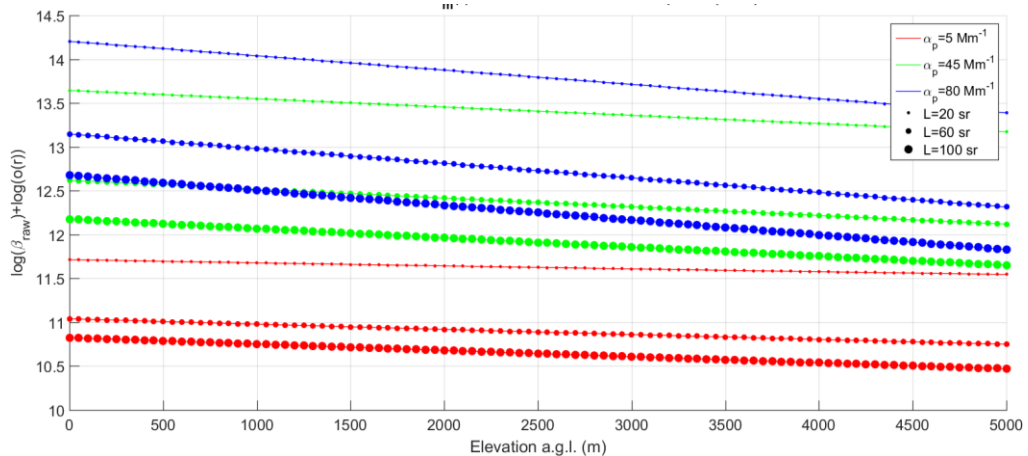


Figure 1: illustration of Equation 7 assuming constant aerosol extinction coefficient ($\alpha_p = 5; 45$ and 80 Mm^{-1}) and constant Lidar Ratio ($L=20; 20$ and 100 sr). The calibration constant was calculated following Wiegner and Geiß m (2012) methodology and was estimated at 3.6 e+11 m.sr . The molecular backscatter was calculated from the US standard atmosphere following Bucholtz (1995) .

We decided not to include this figure in the text as it can be easily reproduced.

- p. 6, l. 7: An illustrative example of this fit would be helpful to visualize this procedure.

Figure 1 (left panel) was added to illustrate the fit.

- p. 6, l. 9-10 and Eq. (9): How does this correction function looks like? Can you give an example?

Figure 1 (right panel) was added to illustrate the correction function.

- p. 7, l. 12-13 and Fig. 1: There are surprisingly few areas for the fitting procedure. Is this enough to obtain a proper correction function? Of course, it shows off in the overlap function plots, but anyhow it seems little information for a strong correction. Please outline, why this is working so well! May be a short review of the Sasano et al. (1979) method (already in the introduction) would help to elucidate this.

There are few areas because we are very restrictive. This restrictiveness is also the reason why it works so well. In principle only one (perfect) profile would be sufficient.

- p. 7, l. 20-21: Why is the elimination of the artefact-line above 250 m not visible from the overlap function? Because it is the difference between the manufacturers and corrected overlap function. This fact could be illustrated in Figure 2 as well.

As the reviewer suggested, it is not visible from the overlap function itself (figure 3, previously figure 2), because the artefact in the gradient is due to the difference between the growth rates of the corrected and the uncorrected functions.

From the authors' point of view, this fact is visible in the new figure 1 and in the figure 7 (previously figure 6).

- p. 9, l. 4 and 5: relative difference ... of what?

The relative difference is now defined as: "relative difference between the corrected and uncorrected signals".

- p. 9, l. 8: 153 daily corrections - > daily overlap function corrections.

Corrected.

- p. 9, l. 13-17: Does this mean that in the end the overlap function has the same shape, but does only vary by internal temperature and will thus be chosen after the measured internal temperatures and not be calculated again? Or will actual overlap functions be calculated continuously and added to the existing ensemble?

Yes, the aim of the model is to be able to apply the overlap correction after measuring the internal temperature. Once the model is determined, it is not necessary to recalculate overlap functions from the data.

- p. 10, l. 4: please refer to Appendix for S. Note, that in the lidar community S is often used for the lidar ratio.

A reference to Appendix A was added.

- p. 10, l. 10-21: and Fig 7: For clarity please relate /or replace 'daily correction' to 'overlap correction' and 'model correction' to 'temperature correction'.

The term 'daily correction' is now defined at the end of section 3.

- p. 10, l. 29: Why is the spike at 360 m, if the artefact in the data is at 250 m?

The overestimation of the range corrected signal (artefact) is centred at 250m. Above this artefact, an artificial gradient is created by the overestimation. The altitude of this artificial gradient is 360m.

- p. 11, l. 1 and 3: detections... of what? Be more precise!

Corrected.

- p. 11, l. 21: A straight line or a linear dependence?

Straight line was replaced by "polynomial of degree one".

- p. 11, l. 30: It was assumed... On what premises? Why is this plausible?

It was demonstrated on figure 5 and 6.

- p. 12, l. 1: Finish this sentence after 'instrument'. And start the next one a: This is the other...

Corrected.

- p. 12, l. 6: Two dots at the end of a sentence. 'year..'

Corrected.

- p. 13, l. 3: Shortly denote the parameters as R_x , κ_1 – κ_{11} , in the text here, so that the reader also can follow without studying Table 2.

It is now briefly mentioned at the start of the appendix that R and kappa are described in Table 2. The aim of Table 2 is to make the text more readable by avoiding an unnecessary description of the parameters in the text.

- p. 13, l. 9: if -> whether

Corrected.

- p. 13, l. 16: Explain $R_{max,max}$ before you use it: move line 16 before line 14.

See comment for p.13, l.3

- p. 13, l. 33: Give explanation of S also in the text on p. 10 (see remark above).

Corrected.

- p. 14, l. 3-9: Long sentences, please shorten.

We revised these sentences and tried to improve the readability. However, the technical nature of the content makes it difficult to shorten and simplify the text.

- p. 14, l. 19 and 24: Sobel operator is not common to me. Short explanation (edgedetector, high-pass-filter) or at least a reference.

The Sobel operator is now defined as: “convolution-based edge detector”.

- p. 15, l. 21, 22, 24: Please note in the text that these κ_x are explained in Table 2!

See comment for p.13, l.3.

- p. 16, l. 28: S-G filter: reference?

Reference added.

- English: ‘has been, have been...’ is often used where simple perfect is more adequate: Rather use ‘was’ and ‘were’ at several instances.

We tried to improve the English throughout the entire manuscript and paid special attention to the use of the tenses.