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Atmospheric Measurement Techniques Discussions

Interactive comment on "Aerosol profiling with the JenOptik ceilometer CHM15kx" *by* M. Wiegner and A. Geiß

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We want to thank reviewer #2 for his/her comments and useful suggestions – they helped us to improve the paper. We repeat the points raised by the reviewer and added our comments in italics.

However, there is one aspect of the paper that needs to be improved. The issue of the effect of incomplete overlap at low altitude is well-addressed in Section 4.2 but in Section 2, this issue must also be adequately addressed. As it now stands, Section 2 is potentially misleading to non-expert readers and may even elicit confusion in expert readers. My concerns could be easily and directly addressed by adding text explicitly addressing this issue, e.g. by writing

$$C_L \to C_L \exp\left(-2\int_0^{z_0} \alpha(z')dz'\right)$$

and explaining (as will be expanded upon in Section 4.2) that, for the ceilometer used in this work, z_0 is such that

$$\exp\left(-2\int_0^{z_0} \alpha(z')dz'\right) \approx 1$$

The reviewer is right, our formulation was not as clear as it should be. Following his/her suggestion we mention the requirements to be fulfilled before the lower limit of the integrals in section 2 and 4.2 can be set to z_{ovl}: In section 2 we explain that $\int_0^z$ (as a result of the inversion of the lidar equation, see e.g. Fernald et al., 1972) can be replaced by $\int_{z_0}^z$ if the range of complete overlap z_0 and the extinction coefficients are low (this is the case at 1064 nm and our ceilometer). The revised manuscript reads:

Under realistic conditions the functions Z and N are not calculated starting at the surface ($z = 0$, "integration in forward direction") but from the range of complete overlap z_{ovl}. This is justified if z_{ovl} is small and a wavelength in the near infrared is used, i.e. α and β are small. Both conditions are fulfilled in case of the CHM15kx (see next section for details) and thus

$$\exp\left\{-2\int_0^{z_{\mathrm{ovl}}} [S_p\,\beta_m - \alpha_m]dz'\right\} \approx 1$$

and

$$\exp\left\{-2\int_0^{z_{\mathrm{ovl}}} \alpha(z')\,dz'\right\} \approx 1$$

Thus, the lower limits of the integrals in $Z(z)$ and $N(z)$ can be replaced by z_{ovl}.

(end quote)

So, the second formula mentioned by the reviewer is explicitly used. Consequently, we have adjusted the lower limit of the integral in section 4.2 – this is possible according to the (new) explanation in section 2.

We don't believe that it is necessary to include the full analysis to demonstrate that z_{ovl} can be used as the lower limit in the revised version of the manuscript. However, for the sake of completeness, we want to briefly outline one approach showing that the replacement is justified:

Z is defined as:

$$Z(z) = S_p(z)\, z^2\, P(z)\, \exp\left\{-2\int_0^z [S_p\,\beta_m - \alpha_m] dz'\right\}$$

Introducing

$$Y(z) = S_p\,\beta_m - \alpha_m$$

we can write

$$Z(z) = S_p(z)\, z^2\, P(z)\, \exp\left\{-2\int_0^{z_{\text{ovl}}} Y dz'\right\} \exp\left\{-2\int_{z_{\text{ovl}}}^z Y dz'\right\}$$

For our ceilometer (z_{ovl}=0.15 km and λ=1064 nm) the first integral is

$$\exp\left\{-2\int_0^{z_{\text{ovl}}} Y dz'\right\} \approx 1$$

and consequently we find the equation used in the paper:

$$Z(z) = S_p(z)\, z^2\, P(z)\, \exp\left\{-2\int_{z_{\text{ovl}}}^z [S_p\,\beta_m - \alpha_m] dz'\right\}$$

N is defined as:

$$N(z) = C_L - 2\int_0^z Z(z')\, dz'$$

Again, we split the integral into two terms:

$$N(z) = C_L - 2\int_0^{z_{\text{ovl}}} Z(z')\, dz' - 2\int_{z_{\text{ovl}}}^z Z(z')\, dz'$$

For the first integral, $z' < z_{\text{ovl}}$ is small (and the extinction is low, see above), so we can write

$$\begin{aligned} Z(z) &= S_p(z)\, z^2\, P(z)\, \exp\left\{-2\int_0^z [S_p\,\beta_m - \alpha_m]\, dz'\right\} \\ &\approx S_p(z)\, z^2\, P(z) \\ &= S_p(z)\, \beta(z)\, C_L\, T^2(z) \\ &\approx S_p(z)\, \beta(z)\, C_L \end{aligned}$$

In the third step the equation mentioned by the reviewer is applied. Thus, we get

$$N(z) = C_L \left[1 - 2\int_0^{z_{\mathsf{ovl}}} S_p(z')\,\beta(z')\,dz'\right] - 2\int_{z_{\mathsf{ovl}}}^{z} Z(z')\,dz'$$

As

$$2\int_0^{z_{\mathsf{ovl}}} S_p(z')\,\beta(z')\,dz' \ll 1$$

we finally find the equation used in the manuscript

$$N(rz) = C_L - 2\int_{z_{\mathsf{ovl}}}^{z} Z(z')\,dz'$$

This last point should be emphasized, as for other types of ceilometer systems with a higher z_0 this may not be valid, thus necessitating a potentially bothersome overlap correction.

We agree, and have added the following: For ceilometers with a "constant" lidar constant, absolute calibration in principle should be easier. This is the case for the JenOptik CHM15k before a recent upgrade ("Nimbus") provides a calibration pulse for each signal that might further facilitate the absolute calibration. On the other hand absolute calibration is significantly complicated and subject to potentially large errors if the ceilometer has a large range of complete overlap (e.g. 500 m or even more). Then, a reliable overlap correction is indispensable for calibration.

Interactive comment on Atmos. Meas. Tech. Discuss., 5, 3395, 2012.