Atmos. Meas. Tech. Discuss.,
doi:10.5194/amt-2016-305-AC1, 2017

Atmospheric Measurement Techniques Discussions
Open Access

Interactive comment on "Remote sensing of $PM_{2.5}$ during cloudy and nighttime periods using ceilometer backscatter" *by* Siwei Li et al.

Siwei Li et al.

siweiligm@gmail.com

Received and published: 19 April 2017

We thank Dr. Thomas for providing his comments and sharing his own thoughts which helped to improve the manuscript. This document includes all the comments as well as our responses to every one of them.

General comments: The authors present an interesting study about the application of ceilometer backscatter data for getting information about the air quality at the surface layer which is expressed as the PM2.5 aerosol mass concentration. This is done by means of a regression model which is able to taking into account relevant meteorological parameters. In my opinion the topic of this study is of larger relevance. It shows a way getting almost continuously air quality information at the surface, or more precisely information about the PM2.5 aerosol mass concentration, by using standard measure-

Printer-friendly version

Discussion paper

ment devices which are installed world-wide. Although this may not be enough getting information about the air quality in a manner that will stand up in court, which is an important constraint for governmental organisations, it is an applicable and promising method. The paper is well written and it clearly shows the way the authors followed to get their results. Main assumptions and limitations of the applied method are discussed and results are presented in an appropriate way. The list of references is fairly complete. The topic is well suited for AMT. I therefore have only a few comments and recommendations before the paper can be published.

Specific comments: The authors used the somewhat outdated and no longer officially supported CT25K Vaisala instrument for their study. Although this instrument is still in use at many places it would be helpful for the community knowing about the impact of the instrumental design and the performance of the CT25K w.r.t. the results. Would it e.g. simply be possible to replace the CT25K by e.g. the CL31, the CL51 from Vaisala or by one of the newer Lufft instruments (the CHM15K) ?

Response: Thanks for the comments and suggestion. Sorry for the confusion due the lack of explanation of using CL31 at ARM SGP site in the previous manuscript. Actually, we used Vaisala CT25k observations at the HUBC site but Vaisala CL31 at ARM SGP site based on the data. We added the explanation of the using of CL31 in the revised manuscript. The principle of our algorithm is suitable for most lidars with small overlap distance. So, it is possible to replace CT25K by the CL31 since they are very similar. For the Lufft, it is a little difference since the full overlap distance of Lufft is higher than Vasaila ceilometer, so the integrated height may be different from that of the Vaisala ceilometer. We added the corresponding explanation in the revised version.

The overlap of the CT25k can't be zero since the mirror is in the optical path of the laser beam. The overlap range is about âĹij30 m for the CL31 and since the CT25K is kind of a predecessor instrument with similar optical design, it is likely the same for the CT25K. I guess the authors actually wanted to say that they are able to retrieve (probably) useful information down to the height of the ceilometer, or in other words, that the built-in overlap correction works down to the surface level. Could be clarified in the text.

Response: Thanks for the comments. Yes, there are several studies discussed the near-field problem of the Vaisala ceilometer for aerosol retrieval. But, based on the CT25 manual and Münkel et al., (2007), the overlap of the CT25k can be zero due to its single lens optical design. Münkel et al., (2007) introduced CT25k as “Vaisala ceilometer CT25K, which is a single lens lidar system equipped with pulsed near-infrared diode lasers. . ..A beam splitter gives full overlap of the transmitter and receiver field-of-view already at an altitude of 0m.” Markowicz et al. (2008) showed that reduction of a signal due to the near-field problem (could be other design issue other than overlap) of CT25k was already compensated by the manufacturer’s correction. In addition, to avoid the possible near-field problem, we conducted a sensitivity test by changing the upper bound of the backscatter integration from 90 m to 300 m and there was no significant different found. So, we thought the overlap and near-field problem could be not a critical issue in this study and then we introduced the Vasaila ceilometer overlap distance along with the CT25k manual and Münkel et al., (2007) with the citation in the manuscript.

The CT25K, as well as other ceilometers, is an uncalibrated instrument. Therefore, the backscattered radiation is variable from instrument to instrument, depending on the laser power, the age of the laser, possible optical distortions, and production tolerance a.s.o. The necessity of calibrating the ceilometer for this application should be discussed. An explaining paragraph should be added since this is a major drawback for the application to other places and other instruments, even of the same instrument model.

Response: Thanks for the comments and suggestions. We agree with that the backscattered radiation is variable from instrument to instrument and depends on a lot of factors including hardware and software. That could induce the different model parameters for different ceilometers in fitting. We added the discussion about the calibration of the ceilometer and the reference (Kotthaus et al., Atmos. Meas. Tech., 9, 3769–3791, 2016) in the discussion section in the revised version.

During a recent ceilometer intercomparison campaign (see http://ceilinex2015.de, paper by S. Kotthaus et al., Atmos. Meas. Tech., 9, 3769–3791, 2016) it became clear that firmware issues can have a large impact on aerosol retrieval results. Did the authors check the firmware versions of the two instruments used in this study? If the authors found a difference there I recommend adding a discussing paragraph.

Response: Thanks for the comments and suggestions. Actually, we used two different ceilometers at HUBC site (CT25k) and at ARM SGP site (CL31). We added the explanation of the using of CL31 in the results section in the revised manuscript. The system noise and artefacts (could be due to hardware and firmware) can have a large impact on aerosol retrieval results especially for small signal-to-noise ratio. The signal-to-noise ratio of the ceilometer decreases with height. In our study, we only used ceilometer backscatters at low altitude and conducted hourly average. So, the signal-to-noise ratio is large in this case. In addition, the regression model relies on the relative change of backscatter corresponding to the change of PM2.5. The systematic artefact impacts should be small on the perforce of the regression model. However, since both the aerosol types and instruments are different at HUBC site and ARM SGP site, the model parameters of the regression model are different at the two sites. We added the discussion in the discussion section in the revised version.

The applicability of the regression model to "any" aerosol composition thus "any" geographic area is limited. The authors analysed situations with predominantly sulphate components. If however larger aerosol particles, e.g. mineral dust advected from the American and Mexican deserts become part of the game the ceilometer backscatter will largely change. Same for coastal zones with dust and sea salt in the atmosphere. It would be helpful if the authors discuss the impact of different aerosol types in a corresponding paragraph.

Response: Thanks for the comments and suggestions. We agree with the reviewer that the regression model won't be the same (the model parameters can be different) at different geographic area. The aerosol composition at HUBC site is different from the aerosol composition at ARM SGP site, so the model parameters are different at the two sites. That is because the relationship between PM2.5 and aerosol backscatter is related to aerosol types and sizes (Li et al., 2016) and the relationship between meteorological conditions and aerosols could also vary for different aerosol types or climatic regions. We added the discussion in the discussion section in the revised version.

Section 3.1: It is somewhat surprising that different fits/models are required for daytime cloudy and daytime clears-sky scenes. The reason for this should be explained in a paragraph. The approach would be better applicable if just two fit data sets are required, a daytime and a night-time data set. What makes the cloudy scene so different from the clear-sky scene ?

Response: Thanks for the comments and suggestions. The reason for why we separated clear sky scenes from cloudy and nighttime scenes is that the observations of AOD and Angstrom exponent are generally only available under clear sky scenes but not under cloudy and nighttime scenes. So, under clear sky scenes, there are more information can be added in the model to improve PM2.5 retrieval (Li et al., 2016). The main purpose of this study is to illustrate the capability of ceilometer to retrieve PM2.5 under cloudy and nighttime situations while most other remote sensing methods are only available under clear scenes. So we separated the clear scenes from the cloudy scene.

Technical corrections: P 5, Eqs. (9) and (10): It might be better renaming the fit coefficients a0,. . .,a4 and b1, b2 in Eq. 10 to c0,. . .,c4, d1, d2. The reader might assume that these coefficients a,b are the same as above, which is according to Tabs. 1,2 not the case.

Printer-friendly version

Discussion paper

Response: Thanks for the comments and suggestions. We changed that in the revised version as the reviewer suggested.

P6., line 7: explain COD

Response: Thanks for the comment. We explained COD as "cloud optical depth (COD)" in page 3, line 26

P11, p12, Figs. 9, 10: The y-axis up to 80 microgram/m**3 makes actually no sense since values higher than 60 do not exist. Maybe the plots are also more conclusive if the x-axis has a similar scale from 0 to 60 in steps of 10 micrograms/m**3.

Response: Thanks for the suggestion. There are several cases having measured PM2.5 value close to 80, so we use the 80 as the upper bound for both x-axis and y-axis. We used the same scale for x-axis and y-axis in the revised version as the reviewer suggested.

P 20, table captions, Eqs. (11) and (12) do not exist, should be 9 and 10 instead, as far as I understood it.

Response: Thanks for the correction. Yes, they should be Eq (9) and Eq (10). We corrected that in the revised version.

Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2016-305, 2016.