

On the Correction a Ceilometer Overlap Function

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Abstract: The measurements of two ceilometers deployed at different heights on a single mountain are compared with the aim of deriving the overlap function of the mountain top ceilometer. Various parameters are analyzed in order to check their influence on the resulting overlap function. It is shown that the method gives good results, especially for overlap values below 0.8 where the noise basically does not affect the results. Furthermore, it is shown that the derived overlap function is relatively stable over time. The temporal variability is much smaller than for the ceilometer of the same type in [1].

1. Introduction

The overlap function of a ceilometer or a lidar is very important in the near range for the determination of the particle backscatter. Usually the overlap function (ovl) of an ALC (automated low-power lidar ceilometer) is provided by the manufacturer. The accuracy and temporal stability are unknown for the user. [1] showed that the ovl of a ceilometer of type CHM15k depends on the internal temperature and they obtained a correction function. The determination of this ovl correction depends on the assumptions of a homogeneous boundary layer and a correct overlap function (provided by the manufacturer) between full overlap down to a certain range (approx.. 600...700 m in [1]).

In this work another method for obtaining an ovl is introduced and analyzed. It is based on the use of 2 ceilometers of the same type which are located at different heights. Hence the assumption of a homogeneous boundary layer is not necessary.

2. Location and Instrument Description

Two ceilometers of the same type CHM15k are operated at different heights (asl). One device is deployed at the top of the Hohenpeißenberg mountain in about 977m asl (denoted as MOHP) whereas the other ceilometer is installed in the valley at an altitude of about 713m asl (denoted as ICOS). Both devices are pointing vertically. The horizontal distance of both devices is approximately 1.5 km.

The wavelength is 1064 nm. Each ceilometer measures a profile with a vertical resolution of about 15 m and a temporal resolution of 15 s. The instrument's ovl function is provided by the manufacturer.

3. Methods

The underlying assumption of the method is that the error in the attenuated backscatter value at the same height is smaller for the valley ceilometer than the mountain top ceilometer and hence the valley ceilometer can be used as a reference for the mountain top ceilometer. This assumption is based on the fact that the overlap correction for the same height (not range!) is much smaller for the valley ceilometer than for the mountain top ceilometer.

Before determining an improved ovl function the measured data were temporally averaged. This should ensure that horizontal aerosol inhomogeneities can be neglected. Then the data of the reference ceilometer (valley) were resampled to match the discrete height points of the mountain ceilometer. Note, the reason that the data of the reference ceilometer were resampled and not the data of mountain top ceilometer lies in the fact that only 1 resampling is necessary in order to calculate a new overlap function for the mountain ceilometer. Otherwise, the resampling should be done twice (1 time for the determination of the improved overlap function and 1 time for the discretization of the new ovl to the range bins of the mountain top ceilometer).

Finally, the attenuated backscatter of both instruments was normalized in a height range where the overlap is complete. Consequently, errors in the attenuated backscatter introduced by an imperfect calibration are removed.

4. RESULTS

Before the overlap could be analyzed and calculated, it is necessary to verify that both ceilometers are pointing vertical. A cirrus cloud is suited. For cirrus above 11 km, it is possible to detect a pointing error as small as 3° which would result in a height mismatch larger than 15 m corresponding to 1 bin. Consequently, the respective error in the overlap region would be very small (max. 2 m). Figure 1 shows the averaged attenuated backscatter for both ceilometers of a high cirrus cloud exhibiting that the cloud base is essentially the same and hence demonstrating that both ceilometers are pointing vertical.

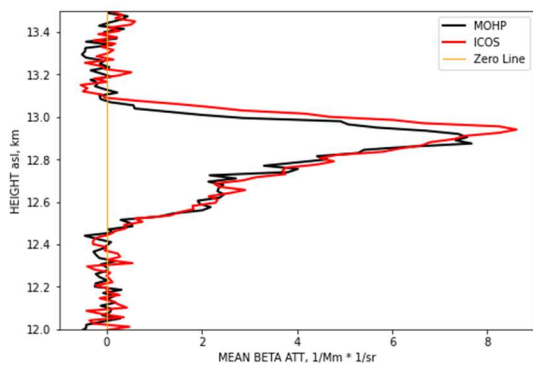


Figure 1. Vertical alignment check (17 Dec. 23, averaged between 21-22 UTC)

One also needs to make sure that the atmosphere above both ceilometers is more or less identical. Sometimes a cloud might be above one ceilometer but not above the other. Such situations have to be rejected.

Ceilometers, in contrast to high power lidars, have a relatively low signal-to-noise-ratio (SNR). For testing the sensitivity of the results on the SNR various time averages are investigated. Figure 2 shows the overlap calculation results for various averaging periods ranging from 15 min up to 3h30m.

One can see that the overlap function is more or less smooth up to a value of approx. 0.8 (range = 550 m). Above this range, the noise comes into play and, as expected, the longer the averaging time the smoother and less noisy the

resulting overlap. Hence for the calculation of the overlap function in the lower range relatively short averaging times can be used. However, for the upper range, one should average the data for 1h or more at least.

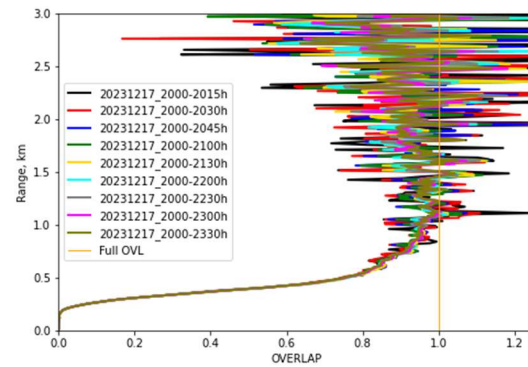


Figure 2. Derived overlap functions for different averaging times (see legend).

A clear stable winter day is chosen for the investigation of potential temporal variability of the derived overlap function. Figure 3 displays the quicklook for the 23 Dec. 2023. The atmosphere did not change much along the day.

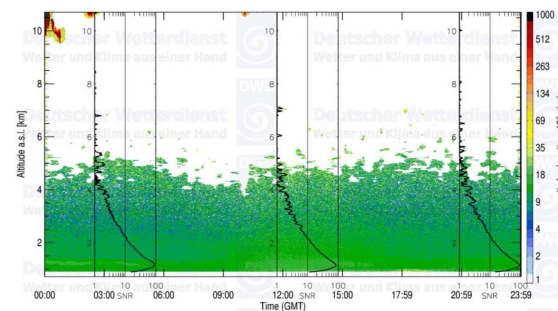


Figure 3. Quicklook of the attenuated backscatter for the 17th Dec. 2023 as measured with the valley ceilometer. The three vertical profiles show the SNR.

The overlap function of the mountain top ceilometer was derived for different times always as 1h average. It is shown in figure 4. One can see that the results are quite stable. Only above the complete overlap the derived function is very noisy.

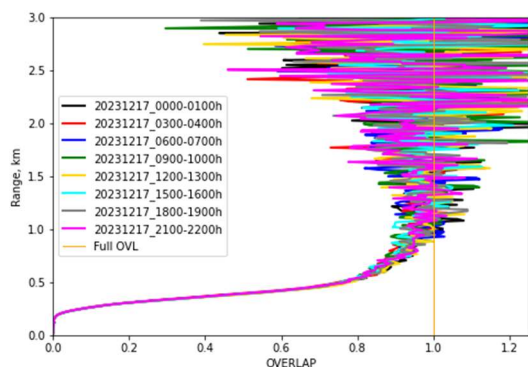


Figure 4. Overlap results for the mountain ceilometer for different times during the same day

Comparing summer and winter data is one possibility to investigate the temperature sensitivity of the derived improved overlap function. Figure 5 shows as an example 4 improved ovl functions, 2 in summer, 2 in winter, 2 during night-time, 2 shortly after noon. The internal temperature covers a range between 15 °C and 37 °C. The variations in the improved overlap function are considerably lower than in [1].

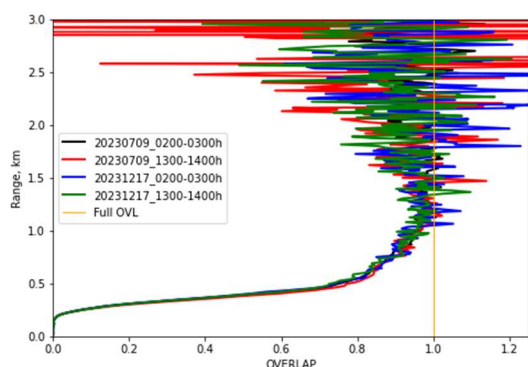


Figure 5. Derived ovl function for different Dates (9 Jul 23 and 17 Dec 23) and times (see legend)

5. Outlook

The Hohenpeissenberg Meteorological Observatory operates several ceilometers of different types (different manufacturer, different wavelengths). This enables extending the method based on comparisons for devices which are operated side by side and cannot benefit from a vertical shift. In that case one needs to assume that the aerosol type does not change over the range of interest, meaning that

the wavelength dependent Angstrom exponent is constant.

6. References

- [1] Hervo et al., “An empirical method to correct for temperature-dependent variations in the overlap function of CHM15k ceilometers,” *AMT* **9**, 9, 2947–2959 (2016).