

Proposal of Extensions for the Telecover Test for Experimentally Determining the Height of Full Overlap

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Abstract: The telecover test is well known and accepted as a tool to experimentally determine the height of full overlap between receiver field-of-view and laser beam. The established test procedure is applicable to individual signals for the retrieval of backscatter profiles from elastically backscattered signals only. This manuscript proposes extensions for the method which can be applied on the retrieval of optical properties from signal ratios (e.g. Raman backscatter profiles) or from signal slopes (extinction profiles) as well as a way to reduce the influence of atmospheric variability.

1. Introduction

The so-called telecover test is well known and widely used in the EARLINET community in order to determine experimentally the height of full overlap between receiver field-of-view and laser beam. The method was first proposed by Volker Freudenthaler [1], and has been optimized over the years. Now, we have a very detailed operation procedure (QAP) [2], and analysis software (ATLAS) [3] provided by the topical centre for aerosol remote sensing (CARS) of the Aerosol, cloud, and trace gas research infrastructure (ACTRIS).

In its current version, the telecover method is focused on the analysis of individual signals and provides the lowest height above which backscatter coefficient profiles can be calculated with the Klett-Fernald algorithm [4,5]. This manuscript proposes extensions for the method which can be applied to the retrieval of the lowest height of Raman backscatter and extinction profiles.

2. Established Telecover Test

A telecover measurement is performed by partly covering the telescope with a non-transparent material. In its basic form for bistatic lidars, the covering device exposes only a one-quarter sector of the telescope area for backscattered light. Measurements are taken with the cover rotated by 90° so that signals are obtained from different parts of the telescope. These sectors are called north, east, south, and west. One can assume that the overlap is complete at the altitude where the signals from

all four sectors are the same. The ACTRIS QAP suggests to repeat the measurement cycle several times.

The telecover measurement shown in this paper was performed with the RALPH (Raman Aerosol Lidar PollyXT at Hohenpeißenberg) instrument at Hohenpeißenberg observatory on March 8, 2024 between 21:30 and 22:30 UT. RALPH is a PollyXT lidar at the Meteorological observatory Hohenpeißenberg which is a candidate for an ACTRIS aerosol remote sensing site.

Measurements with the four sectors were taken alternately in 5 iterations. The data of each iteration contain 10 profiles each averaged over 10 seconds. The periods between iterations have lasted only approximately 20 seconds.

Figure 1 presents the traditional analysis of the telecover test for the measurement channel of the parallel polarized component of the elastically backscattered light at 532 nm (channel 532p). The top panel shows range- and background corrected signals which were averaged over the 5 iterations per sector. As expected, the signal increases first in the north sector which is closest to the laser beam, then at east and west sectors and finally also in the south sector. Obstacles in the optical path can cause different absolute values of the signals. Therefore, all signals were normalized to the height range between 1.5 and 2.5km (middle panel). The bottom panel shows the relative deviations of all normalized signals from the mean over all sectors (grey line in middle panel)

and the root mean square deviation (RMSD) of all sectors.

According to the QAP, the signal can be used for backscatter retrievals starting from an altitude where the relative deviation is not larger than 5%. In this measurement example, this condition is fulfilled at a height of 1000 m.

3. Extended Telecover Test

The existing methodology is well applicable for the retrieval of backscatter profiles from elastically backscattered signals only. The following section discusses an extension of the telecover method for retrievals of optical properties

- Based on signal ratios
- Based on signal slopes
- In the presence of signals measured simultaneously with another (e.g. near-range) telescope

3.1. For Signal Ratios

In the case of backscatter retrievals with the Raman method [6] or of volume linear depolarization ratios (VLDR), the calculations are not based on a single signal, but on a signal ratio. If the lidar instrument is well designed, the nominator and denominator signals should

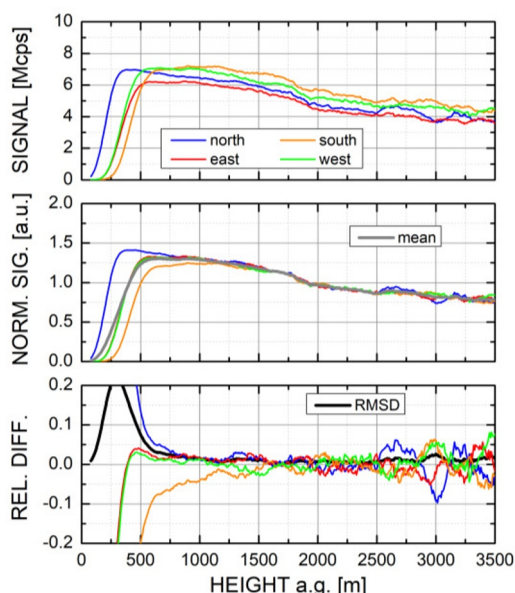


Figure 1. Telecover measurement of channel 532p. top: range- and background corrected signals, middle: normalized signals (normalization range is 1.5-2.5km), bottom: relative deviations from the mean over all sectors.

have the same or similar optical overlap functions. When calculating the signal ratio, both overlap functions can be cancelled. It is well known that Raman backscatter profiles and VLDR profiles can be derived at lower height ranges than elastic backscatter profiles. But no instrument is perfect and the assumption of identical overlap functions of both signals has its limits. Now, the telecover method provides a very useful tool to determine those limits. If the method is applied to the signal ratios measured in the different telescope sectors, the deviations from the mean indicate the minimum height above which the assumption of equal overlap functions is valid.

Figure 2 presents the same telecover test as Figure 1, but for the ratio between the parallel polarized component of the elastically backscattered signal at 532nm and the Raman signal at 607nm (channel 607). The relative deviations are much smaller than from the established method. Except in sector south, significant deviations from the mean occur below 500m height. This test reveals a problem with the data from the south sector, which needs further investigation.

3.2. For Signal Slopes

In the case of extinction retrievals with the Raman method [6], the retrieved profile strongly depends on the vertical slope of the Raman signal. The established telecover method is not sensitive enough to really detect

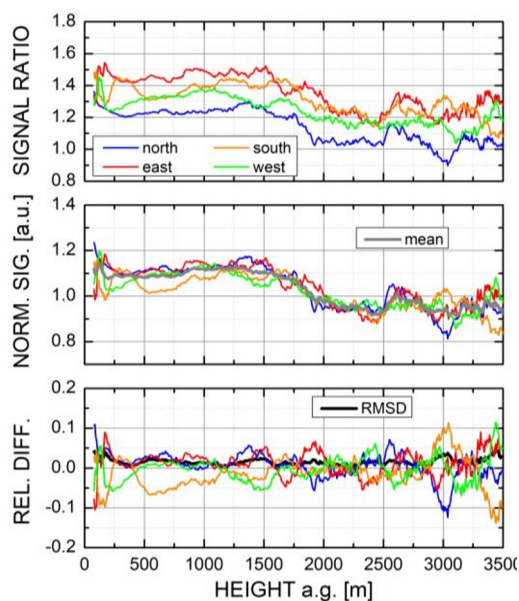


Figure 2. same as Figure 1, but for the ratio of signals 532p and 607.

the height of full overlap with the required accuracy. But, the sensitivity of the method can be improved by applying the test to the derivative of the Raman signal instead of the measured signal itself.

Unfortunately, the Raman signals of the presented telecover measurement are too noisy to calculate proper signal slopes. The telecover test has to be repeated with a reduced set of neutral density filters in the Raman channel.

3.3. With Reduced Influence of Atmospheric Variability

In the case of lidar systems with multiple telescopes, the QAP suggests to close all telescopes which are not involved in the current test in order to avoid confusion. But, data from other (e.g. near-range) telescopes can help to compensate for atmospheric variability during the test measurement. The QAP suggests to perform telecover tests only under atmospheric conditions that do not change with time. But those conditions might be difficult to find at some locations. Therefore, applying the telecover test to signal ratios can help again. E.g., RALPH has an additional near-range telescope with a total 532 nm channel (channel 532near) and a Raman channel at 607nm (channel 607near).

If the tested lidar system does not have a near-range telescope, one could probably also use the data of a nearby ceilometer if its signal quality

is sufficient and the wavelength fits to the investigated channel.

Figure 3 presents the same analysis as Figure 1, but for the ratio of signals 532p and 532near. The ratio profiles are quite noisy due to the noisy data of the near-range signal. Nevertheless, deviations are reduced, especially in the height range between 800 and 1500m. From the analysis of Figure 3, one would retrieve a minimum height of 800m for the retrieval of a backscatter coefficient from the elastically backscattered signal at 532nm.

Figure 4 illustrates the atmospheric variability during the telecover measurement. Two aerosol layers have been present during the test measurement. The gap between the layers increased during the test period while the top height of the layers remained stable.

4. Results

Figure 5 shows backscatter profiles measured with RALPH on 2024-03-20 between 1:30 and 3:30 UT. The comparison with the Raman backscatter profile from the near-range signals indicate that the estimated minimum heights as described in sections 3.1 and 3.3 agree very well with the height points where the profiles start to deviate. The minimum height of 1000m as derived with the established method seems to be too high.

5. Conclusions and Outlook

This manuscript proposed extensions to the well established telecover test method. Based on one example telecover measurement with the RALPH lidar, it could be shown that the extensions for signal ratios and the reduction of atmospheric variability work well. But, the test

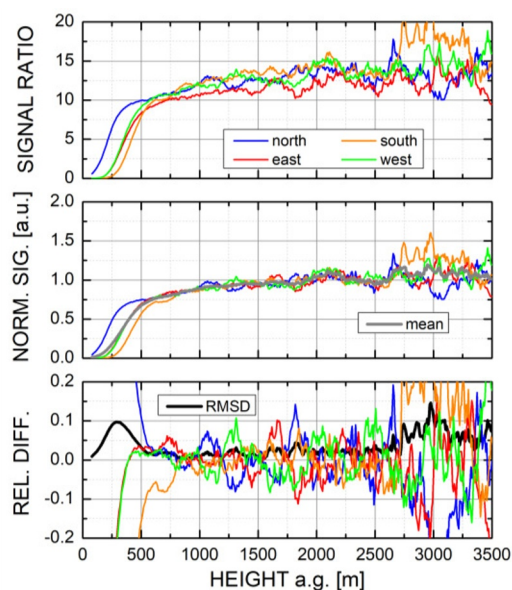


Figure 3. same as Figure 1, but for the ratio of signals 532p and 532near.

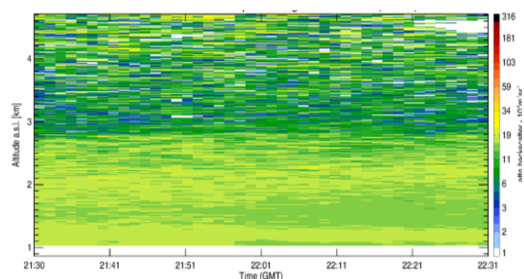


Figure 4. Attenuated backscatter at 1064nm measured by a ceilometer CHM15k during the telecover test. The ceilometer is located in approximately 2 km distance to the lidar and 250m below the lidar altitude.

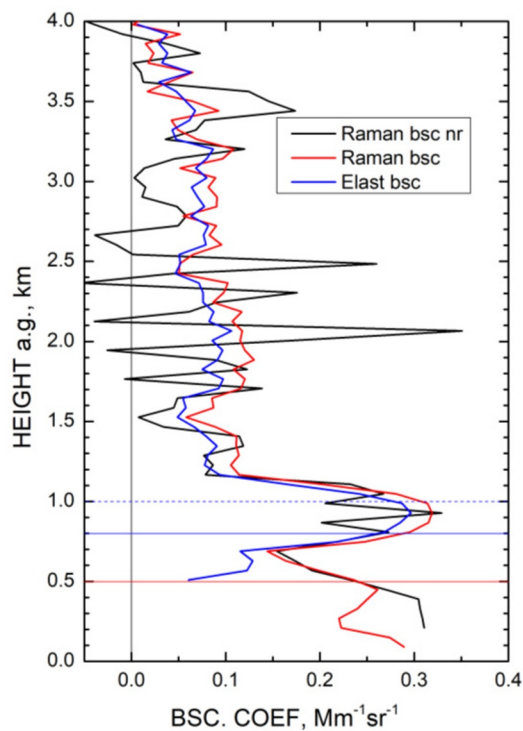


Figure 5. Profiles of the particle backscatter coefficient, obtained with Raman and Klett-Fernald methods from signals from the normal and the near-range telescope, respectively. The averaging time is 2 hours. Horizontal lines indicate the minimum profile heights as obtained in sections 2 and 3 with the established and the extended telecover test.

measurement for signal slopes needs to be repeated with improved conditions.

In general, more example measurements (probably with data from another lidar instrument) are needed to verify the applicability of the suggested extensions.

6. References

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