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Absolute calibration of the Jenoptik CHM15k-x ceilometer and its applicability for quantitative aerosol monitoring

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The knowledge of the spatiotemporal distribution of atmospheric aerosols and its optical characterization is essential for the understanding of the radiation budget, air quality, and climate. For this purpose, lidar is an excellent system as it is an active remote sensing technique. As multi-wavelength research lidars with depolarization channels are quite complex and cost-expensive, increasing attention is paid to so-called ceilometers. They are simple one-wavelength backscatter lidars with low pulse energy for eye-safe operation. As maintenance costs are low and continuous and unattended measurements can be performed, they are suitable for long-term aerosol monitoring in a network. However, the signal-to-noise ratio is low, and the signals are not calibrated.
The only optical property that can be derived from a ceilometer is the particle backscatter coefficient, but even this quantity requires a calibration of the signals. With four years of measurements from a Jenoptik ceilometer CHM15k-x, we developed two methods for an absolute calibration on this system. This advantage of our approach is that only a few days with favorable meteorological conditions are required where Rayleigh-calibration and comparison with our research lidar is possible to estimate the lidar constant. This method enables us to derive the particle backscatter coefficient at 1064 nm, and we retrieved for the first time profiles in near real-time within an accuracy of 10 %. If an appropriate lidar ratio is assumed the aerosol optical depth of e.g. the mixing layer can be determined with an accuracy depending on the accuracy of the lidar ratio estimate.
Even for "simple" applications, e.g. assessment of the mixing layer height, cloud detection, detection of elevated aerosol layers, the particle backscatter coefficient has significant advantages over the measured (uncalibrated) attenuated backscatter. The possibility of continuous operation under nearly any meteorological condition with temporal resolution in the order of 30 seconds makes it also possible to apply time-height-tracking methods for detecting mixing layer heights. The combination of methods for edge detection (e.g. wavelet covariance transform, gradient method, variance method) and edge tracking techniques is used to increase the reliability of the layer detection and attribution. Thus, a feature mask of aerosols and clouds can be derived. Four years of measurements constitute an excellent basis for a climatology including a homogeneous time series of mixing layer heights, aerosol layers and cloud base heights of the troposphere. With a low overlap region of 180 m of the Jenoptik CHM15k-x even very narrow mixing layers, typical for winter conditions, can be considered.