Algorithm to determine the aerosol pollution layers from ceilometer profiles

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Introduction

The ceilometers were originally designed for cloud base height estimation (CBH) in order to assist the aviation. National ceilometer networks are in place, usually belonging to the national meteorological services such as Met Office and DWD (e.g., Adam et al., 2016). Over the last 10-15 years or so, the ceilometers were taken into account for scientific research and were involved in estimation of the planetary boundary layer (PBL) (e.g., Stachlewska et al., 2012; Lotteraner and Piringer, 2016; Lee et al., 2019), determination of the particles backscatter coefficient (Heese et al., 2010; Wiegner et al., 2014; Cazorla et al., 2017) or pollution monitoring (e.g., Marcos et al., 2018; Adam et al., 2020). Recently, the European automatic lidar and ceilometer network, EPROFILE, was established (https://e-profile.eu/#/cm_profile, last access 20210528) where attenuated backscatter profiles are available in near real time for 499 lidars and ceilometers.

Two Nimbus ceilometers from Lufft (https://www.lufft.com/products/cloud-height-snow-depth-sensors-288/lufft-ceilometer-chm8k-2405/, last access 20210528) were installed at INOE in 2018 and are part of EPROFILE network while one of them is part of CLOUDNET as well (https://cloudnet.fmi.fi/, last access 20210528). The present research topic refers to the development of an algorithm, capable to estimate the tropospheric aerosol layers from ceilometer's RCS (range corrected signal). The script is written in Matlab (https://www.mathworks.com/, last access 20210528).

The main steps of the algorithm are:

- The input RCS profiles are averaged over 1 h and 60 m
- Additional smoothing is performed over 9 bins
- RCS for which SNR < 3 are dismissed
- The variance of the cumulative signal (RCS) is calculated (VCS)
- A new vector is defined as: NV=VCS(1:2:end-1).*VCS(2:2:end)
- Calculate the local maxima (islocalmax in Matlab) of NV which gives the location of the inflection points in NV
- Calculate the local minima (islocalmin in Matlab) of NV which gives the location of the minima and maxima in NV

  The data for which the prominence of the inflection points and the corresponding NV values are smaller than 0.01 is dismissed
- Few other criteria are involved in order to retain the optimum number of inflection points and local minima or maxima
- The first and last 60 m from the bottom and top of the layer are dismissed.

Currently, we apply the algorithm for the profiles which do not have clouds, based on CBH information given in the raw data. However, it can be applied for clouds as well. Once mature, the algorithm will be implemented for the study on near real time alert system. We also plan to adjust it for the lidar profiles used in our research on biomass burning. See the other two presentations by Adam et al., at the conference.

Results and discussion

Figure 1 shows the layers determined on 20210410.

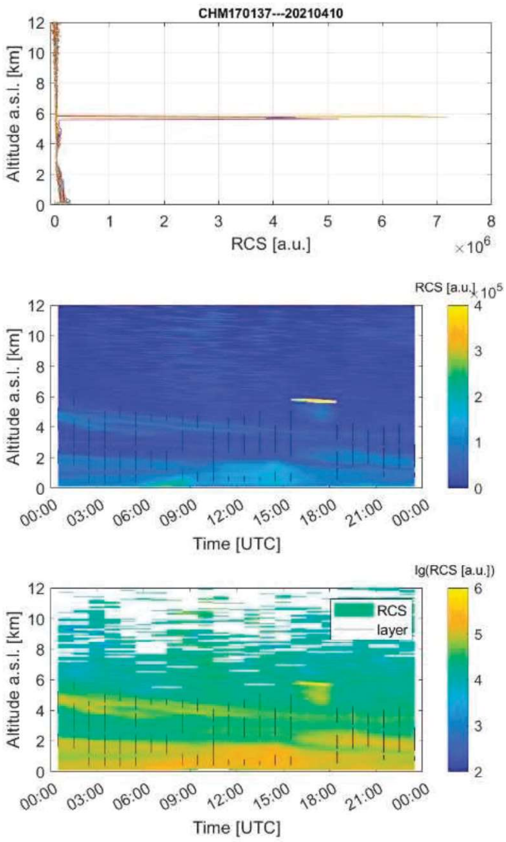

Figure 1. (upper) RCS versus altitude, (middle) RCS versus time and altitude and superimposed layers, (lower) same as middle but with RCS in log scale. Data are from 10 April 2021.

Clouds were observed between 16:00 and 18:00 UTC. We visually observe the presence of several aerosol layers. Thin layers at ~ 5 km altitude (a.s.l.) are observed at 00:00 which descend towards ~ 3.5 km at 24:00. Other layers are observed between 00:00 and 09:00 UTC around 1.5 – 2 km and between 15:00 and 24:00 around 2 km.

Figure 2 shows the profile for 05:00-06:00 UTC and the four layers detected. At a glance, the layers' delimitation looks ok. Figure 3 shown the profile for 11:00-12:00 UTC. Visually, the layers are not accurate. The first layer does not catch the whole PBL while the IInd and the IIIrd layer might have other borders.

A large variety of delicate situations will be discussed during conference while comparisons with the gradient method will be shown.

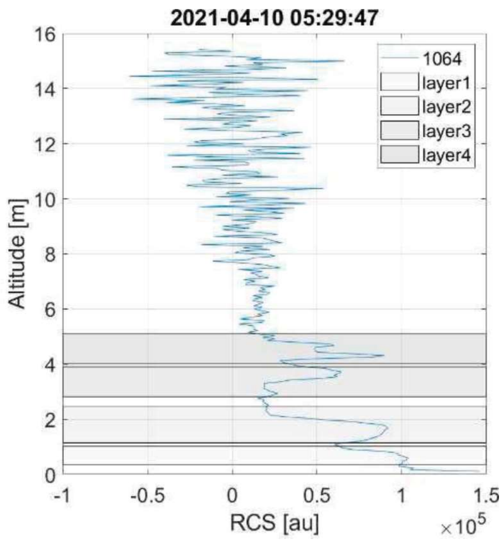

Figure 2. RCS profile for 05:00-06:00 UTC, 10 April 2021 and the estimated layers.

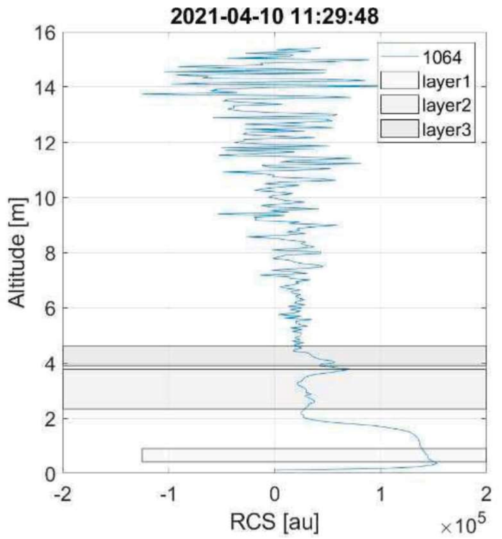

Figure 3. RCS profile for 11:00-12:00 UTC, 10 April 2021 and the estimated layers.

Challenges

The main challenges for pollution layers estimation are the following:

- Layer definition.
- How to proceed with multiple adjacent thin layers?
- Low SNR in ceilometer profiles

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