Boundary layer heights from Ceilometer data

Jan H. Schween

Institute for Geophysics and Meteorology, University of Cologne, Germany , jschween@uni-koeln.de

intro

Ceilometers are instruments to measure cloud base heights by means of a low power lidar. These instruments are optimized to detect the strong return signal of the laser pulse from the cloud base. Nevertheless it is possible to identify the height of the boundary layer and structures therein. Since the instrument works continuously it might be a powerful instrument to understand the diurnal course of the boundary layer.

basic idea

Modern ceilometers deliver the backscatter coefficient β as a function of height based on an application of the Klett algorithm with a constant lidar ratio.

Within the boundary layer concentrations of aerosols are higher than in the free atmosphere above. Thus the backscatter coefficient drops at the top of the boundary layer.

The main amount of atmospheric aerosol is in the boundary layer. The integral of β from the ground – a measure of the optical depth – should reach a plateau.

method

- Smooth data in space and time
- Determine $\tau(z) = \int_0^z \beta(z')dz'$ and τ_{top}
- Plateau where $\tau(z_{i\max}) = q \cdot \tau_{top}$
- Determine steps of β : $\frac{d\beta}{dz} = \min \Leftrightarrow \frac{d^2\beta}{dz^2} = 0$ and $\frac{d^3\beta}{dz^3} < 0$
- Sort steps by strength, filter for magnitude

example

Measurements made with a Vaisala ct25k close to Jülich in NW Germany on 27.8.2007 (Fig.1) show during daytime obvious scatter in the upper parts of the profiles. If clouds are apparent the scatter becomes larger. Since the derivative of β will be examined it is essential to smooth the data.

The first look to the data already reveals an upper boundary of the aerosol layer between 1km and 1.8km, structures therein before sunrise at 6:45UTC and a rising layer of stronger backscatter between 8 and 12 UTC

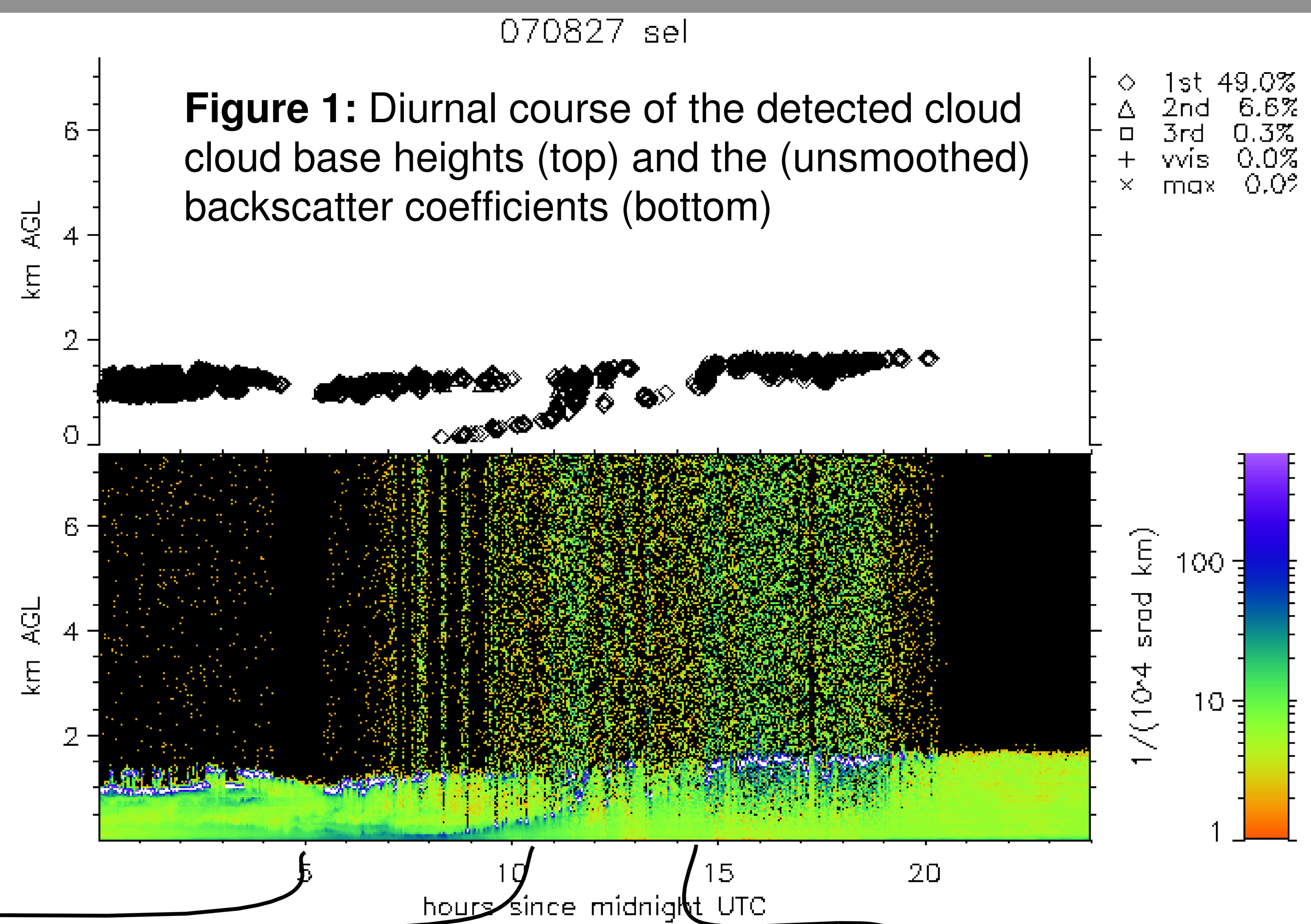


Figure 1: Diurnal course of the detected cloud cloud base heights (top) and the (unsmoothed) backscatter coefficients (bottom)

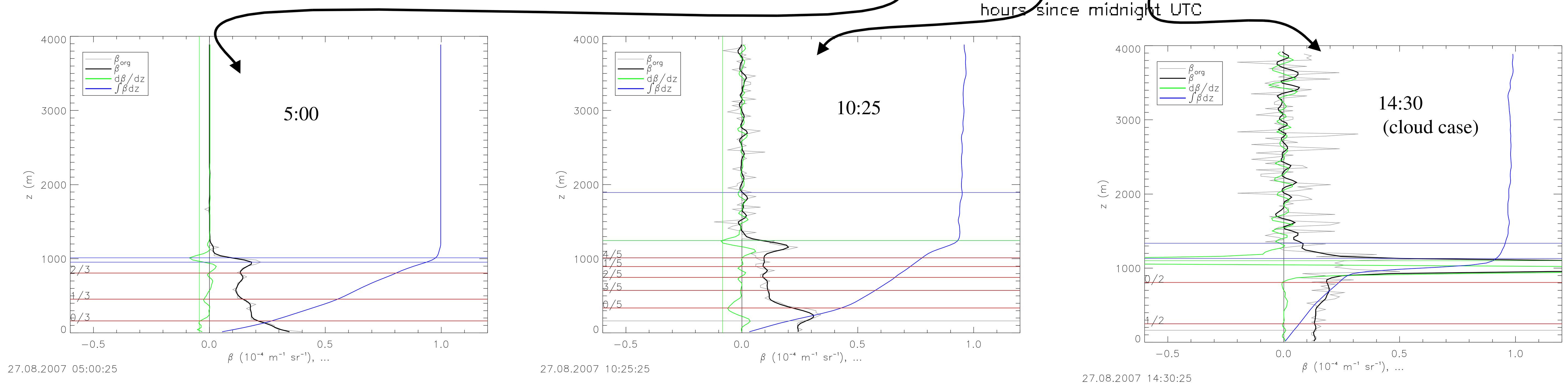
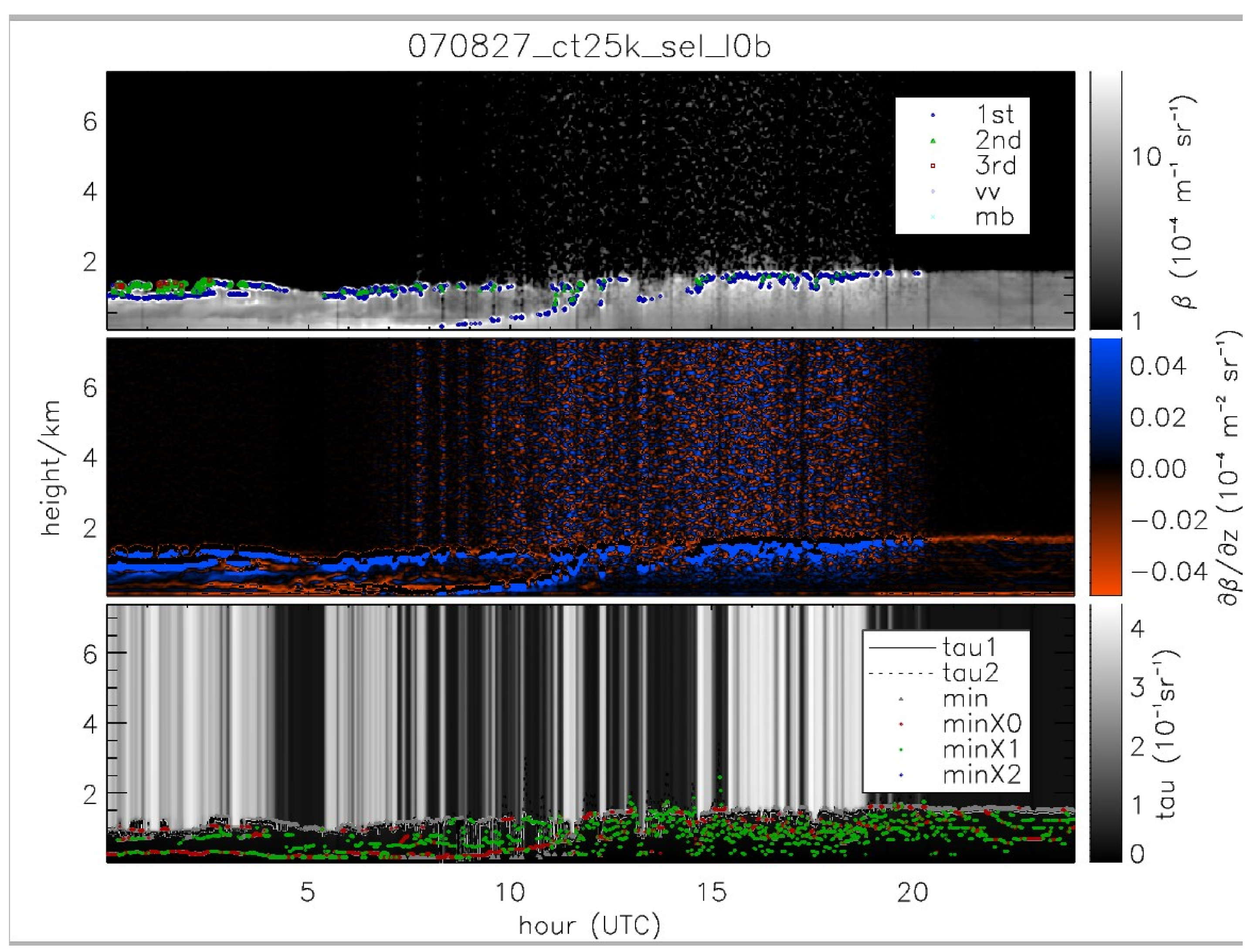


Figure 2: Profiles of backscatter coefficient β its derivative $d\beta/dz$ and integral τ at 5:00, 10:25 and 14:30 UTC. Heigths from the plateau argument (blue) and steps in the β -profile (red) as well the absolute minimum of $d\beta/dz$ (green)

backscatter profiles

The profiles show clearly the noise during daytime and the cloud case at 14:30 (Fig.2). Smoothing in space and time reduces this sufficiently and makes an examination of the derivative possible. The strongest derivative gives in most of the cases during daytime the probable height of the boundary layer.

The cloud case shows that the signal below the cloud becomes noisy as well. Beside this a convective cloud makes the top of the boundary layer invisible and a derivation of the boundary layer height becomes impossible.



derived heights

Derived heights are shown in Fig.3. The heights from the plateau argument show a good agreement with the visually derived detected top of the aerosol layer and are mainly not influenced by the noise.

During daytime the noise remaining in the smoothed backscatter coefficients produces a lot of scatter in the heights but in many cases the strongest derivative coincides with the rising boundary layer.

If a cloud comes into the field of view the plateau argument returns a height above the cloud base. It becomes necessary to force the algorithm to use only heights below the first significant increase of β which is in many cases clear below the detected cloud base.

conclusion

Although the instruments main purpose is the detection of cloud base heights it is possible to derive boundary layer- and aerosol layer height from the rather weak and noisy signal in the aerosol layer.

The automatic power adaption of the instrument and the connected varying noise level especially if a cloud comes into the field of view makes the detection algorithm a challenging task.

Figure 3: Diurnal course of the smoothed backscatter coefficients (top) its derivative (middle) and integral together with the derived heights (bottom). Heights from the plateau argument with two different thresholds (q=0.90 for tau1 and 0.95 for tau2 as black lines), the height from the absolute minimum (gray symbols) and the height from the two strongest steps (red and green dots).